

1                   **HIGH POWER UMBILICALS FOR ELECTRIC FLOWLINE**  
2                   **IMMERSION HEATING OF PRODUCED HYDROCARBONS**  
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6                   **PRIORITY FROM U.S. PATENT APPLICATION**  
7

8           The present application is a continuation-in-part  
9           (C.I.P) application of co-pending U.S. Patent Application  
10          Serial No. 10/223,025, filed August 15, 2002, that is  
11          entitled "High Power Umbilicals for Subterranean Electric  
12          Drilling Machines and Remotely Operated Vehicles", an  
13          entire copy of which is incorporated herein by reference.  
14          Serial No. 10/223,025 was published on February 20, 2003,  
15          having Publication Number US 2003/0034177 A1.  
16

17          Applicant claims priority from U.S. Patent Application  
18          Serial No. 10/223,025.  
19  
20

21                   **PRIORITY FROM U.S. PROVISIONAL PATENT APPLICATIONS**  
22

23          The present application relates to Provisional Patent  
24          Application Number 60/432,045, filed on December 8, 2002,  
25          that is entitled "Pump Down Cement Float Valves for Casing  
26          Drilling, Pump Down Electrical Umbilicals, and Subterranean  
27          Electric Drilling Systems", an entire copy of which is  
28          incorporated herein by reference.  
29

30          The present application also relates to Provisional  
31          Patent Application Number 60/448,191, filed on February 18,  
32          2003, that is entitled "Long Immersion Heater Systems",  
33          an entire copy of which is incorporated herein by reference.  
34

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1           The present application also relates to Provisional  
2 Patent Application Number 60/455,657, filed on March 18,  
3 2003, that is entitled "Four SDCI Application Notes  
4 Concerning Subsea Umbilicals and Construction Systems",  
5 an entire copy of which is incorporated herein by reference.  
6

7           The present application also relates to Provisional  
8 Patent Application Number 60/504,359, filed on September 20,  
9 2003, that is entitled "Additional Disclosure on Long  
10 Immersion Heater Systems", an entire copy of which is  
11 incorporated herein by reference.  
12

13           And finally, the present application also relates to  
14 Provisional Patent Application Number 60/523,894, filed on  
15 November 20, 2003, that is entitled "More Disclosure on Long  
16 Immersion Heater Systems", an entire copy of which is  
17 incorporated herein by reference.  
18

19           Applicant claims priority from the above U.S.  
20 Provisional Patent Applications No. 60/432,045,  
21 No. 60/448,191, No. 60/455,657, No. 60/504,359, and  
22 No. 60/523,894.  
23

#### 24           CROSS-REFERENCES TO RELATED APPLICATIONS 25

26           This application relates to Provisional Patent  
27 Application Number 60/313,654 filed on August 19, 2001,  
28 that is entitled "Smart Shuttle Systems", an entire copy of  
29 which is incorporated herein by reference.  
30

31           This application also relates to Provisional Patent  
32 Application Number 60/353,457 filed on January 31, 2002, that  
33 is entitled "Additional Smart Shuttle Systems", an entire  
34 copy of which is incorporated herein by reference.

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1           This application further relates to Provisional Patent  
2 Application Number 60/367,638 filed on March 26, 2002, that  
3 is entitled "Smart Shuttle Systems and Drilling Systems", an  
4 entire copy of which is incorporated herein by reference.  
5

6           And yet further, this application also relates the  
7 Provisional Patent Application Number 60/384,964 filed on  
8 June 3, 2002, that is entitled "Umbilicals for Well  
9 Conveyance Systems and Additional Smart Shuttles and Related  
10 Drilling Systems", an entire copy of which is incorporated  
11 herein by reference.  
12

13           Serial No. 10/223,025 claimed priority from the above  
14 Provisional Patent Application No. 60/313,654,  
15 No. 60/353,457, No. 60/367,638 and No. 60/384,964, and  
16 applicant claims any relevant priority in the present  
17 application.  
18

19           The following applications are related to this  
20 application, but applicant does not claim priority from the  
21 following related applications.  
22

23           This application relates to Serial No. 09/375,479, filed  
24 August 16, 1999, having the title of "Smart Shuttles to  
25 Complete Oil and Gas Wells", that issued on February 20,  
26 2001, as U.S. Patent No. 6,189,621 B1, an entire copy of  
27 which is incorporated herein by reference.  
28

29           This application also relates to application Serial  
30 No. 09/487,197, filed January 19, 2000, having the title of  
31 "Closed-Loop System to Complete Oil and Gas Wells", that  
32 issued on June 4, 2002 as U.S. Patent No. 6,397,946 B1,  
33 an entire copy of which is incorporated herein by reference.  
34

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1           This application also relates to co-pending application  
2       Serial No. 10/162,302, filed June 4, 2002, having the title  
3       of "Closed-Loop Conveyance Systems for Well Servicing", an  
4       entire copy of which is incorporated herein by reference.  
5  
6

7                               Related PCT Applications  
8

9           And yet further, this application also relates to  
10       co-pending PCT Application Serial Number PCT/US00/22095,  
11       filed August 9, 2000, having the title of "Smart Shuttles to  
12       Complete Oil and Gas Wells", that has International  
13       Publication Date of February 22, 2001 and International  
14       Publication Number WO 01/12946 A1, an entire copy of which  
15       is incorporated herein by reference.  
16

17           This application further relates to PCT Patent  
18       Application Number PCT/US02/26066 filed on August 16, 2002,  
19       entitled "High Power Umbilicals for Subterranean Electric  
20       Drilling Machines and Remotely Operated Vehicles", that  
21       has International Publication Date of February 27, 2003,  
22       and has the International Publication Number WO 03/016671 A2.  
23  
24

25                               Related U.S. Disclosure Documents  
26

27           This application further relates to disclosure in U.S.  
28       Disclosure Document No. 451,044, filed on February 8, 1999,  
29       that is entitled 'RE: -Invention Disclosure- "Drill Bit  
30       Having Monitors and Controlled Actuators"', an entire copy of  
31       which is incorporated herein by reference.  
32

33           This application further relates to disclosure in U.S.  
34       Disclosure Document No. 458,978 filed on July 13, 1999 that

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1 is entitled in part "RE: -INVENTION DISCLOSURE MAILED JULY  
2 13, 1999", an entire copy of which is incorporated herein by  
3 reference.  
4

5 This application further relates to disclosure in U.S.  
6 Disclosure Document No. 475,681 filed on June 17, 2000 that  
7 is entitled in part "ROV Conveyed Smart Shuttle System  
8 Deployed by Workover Ship for Subsea Well Completion and  
9 Subsea Well Servicing", an entire copy of which is  
10 incorporated herein by reference.  
11

12 This application further relates to disclosure in U.S.  
13 Disclosure Document No. 496,050 filed on June 25, 2001 that  
14 is entitled in part "SDCI Drilling and Completion Patents and  
15 Technology and SDCI Subsea Re-Entry Patents and Technology",  
16 an entire copy of which is incorporated herein by reference.  
17

18 This application further relates to disclosure in U.S.  
19 Disclosure Document No. 480,550 filed on October 2, 2000  
20 that is entitled in part "New Draft Figures for New Patent  
21 Applications", an entire copy of which is incorporated herein  
22 by reference.  
23

24 This application further relates to disclosure in U.S.  
25 Disclosure Document No. 493,141 filed on May 2, 2001 that is  
26 entitled in part "Casing Boring Machine with Rotating Casing  
27 to Prevent Sticking Using a Rotary Rig", an entire copy of  
28 which is incorporated herein by reference.  
29

30 This application further relates to disclosure in U.S.  
31 Disclosure Document No. 492,112 filed on April 12, 2001 that  
32 is entitled in part "Smart Shuttle™ Conveyed Drilling  
33 Systems", an entire copy of which is incorporated herein by  
34 reference.

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1           This application further relates to disclosure in U.S.  
2 Disclosure Document No. 495,112 filed on June 11, 2001 that  
3 is entitled in part "Liner/Drainhole Drilling Machine", an  
4 entire copy of which is incorporated herein by reference.  
5

6           This application further relates to disclosure in U.S.  
7 Disclosure Document No. 494,374 filed on May 26, 2001 that is  
8 entitled in part "Continuous Casting Boring Machine", an  
9 entire copy of which is incorporated herein by reference.  
10

11           This application further relates to disclosure in U.S.  
12 Disclosure Document No. 495,111 filed on June 11, 2001 that  
13 is entitled in part "Synchronous Motor Injector System", an  
14 entire copy of which is incorporated herein by reference.  
15

16           And yet further, this application also relates to  
17 disclosure in U.S. Disclosure Document No. 497,719 filed on  
18 July 27, 2001 that is entitled in part "Many Uses for The  
19 Smart Shuttle™ and Well Locomotive™", an entire copy of which  
20 is incorporated herein by reference.  
21

22           This application further relates to disclosure in U.S.  
23 Disclosure Document No. 498,720 filed on August 17, 2001 that  
24 is entitled in part "Electric Motor Powered Rock Drill Bit  
25 Having Inner and Outer Counter-Rotating Cutters and Having  
26 Expandable/Retractable Outer Cutters to Drill Boreholes into  
27 Geological Formations", an entire copy of which is  
28 incorporated herein by reference.  
29

30           Still further, this application also relates to  
31 disclosure in U.S. Disclosure Document No. 499,136 filed on  
32 August 26, 2001, that is entitled in part 'Commercial System  
33 Specification PCP-ESP Power Section for Cased Hole Internal  
34

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1 Conveyance "Large Well Locomotive"™', an entire copy of which  
2 is incorporated herein by reference.

3  
4 And yet further, this application also relates to  
5 disclosure in U.S. Disclosure Document No. 516,982 filed on  
6 August 20, 2002, that is entitled "Feedback Control of RPM  
7 and Voltage of Surface Supply", an entire copy of which is  
8 incorporated herein by reference.

9  
10 And finally, this application also relates to disclosure  
11 in U.S. Disclosure Document No. 531,687 filed May 18, 2003,  
12 that is entitled "Specific Embodiments of Several SDCI  
13 Inventions", an entire copy of which is incorporated herein  
14 by reference.

15  
16 Various references are referred to in the above defined  
17 U.S. Disclosure Documents. For the purposes herein, the term  
18 "reference cited in applicant's U.S. Disclosure Documents"  
19 shall mean those particular references that have been  
20 explicitly listed and/or defined in any of applicant's above  
21 listed U.S. Disclosure Documents and/or in the attachments  
22 filed with those U.S. Disclosure Documents. Applicant  
23 explicitly includes herein by reference entire copies of each  
24 and every "reference cited in applicant's U.S. Disclosure  
25 Documents". To best knowledge of applicant, all copies of  
26 U.S. Patents that were ordered from commercial sources that  
27 were specified in the U.S. Disclosure Documents are in the  
28 possession of applicant at the time of the filing of the  
29 application herein.

#### 30 31 Related U.S. Trademarks

32  
33 Various references are referred to in the above defined  
34 U.S. Disclosure Documents. For the purposes herein, the term

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1 "reference cited in applicant's U.S. Disclosure Documents"  
2 shall mean those particular references that have been  
3 explicitly listed and/or defined in any of applicant's above  
4 listed U.S. Disclosure Documents and/or in the attachments  
5 filed with those U.S. Disclosure Documents. Applicant  
6 explicitly includes herein by reference entire copies of each  
7 and every "reference cited in applicant's U.S. Disclosure  
8 Documents". In particular, applicant includes herein by  
9 reference entire copies of each and every U.S. Patent cited  
10 in U.S. Disclosure Document No. 452648, including all its  
11 attachments, that was filed on March 5, 1999. To best  
12 knowledge of applicant, all copies of U.S. Patents that were  
13 ordered from commercial sources that were specified in the  
14 U.S. Disclosure Documents are in the possession of applicant  
15 at the time of the filing of the application herein.  
16

17 Applications for U.S. Trademarks have been filed in the  
18 USPTO for several terms used in this application.  
19 An application for the Trademark "Smart Shuttle™" was filed  
20 on February 14, 2001 that is Serial No. 76/213676, an entire  
21 copy of which is incorporated herein by reference. The  
22 "Smart Shuttle™" is also called the "Well Locomotive™". An  
23 application for the Trademark "Well Locomotive™" was filed on  
24 February 20, 2001 that is Serial Number 76/218211, an entire  
25 copy of which is incorporated herein by reference. An  
26 application for the Trademark of "Downhole Rig" was filed on  
27 June 11, 2001 that is Serial Number 76/274726, an entire copy  
28 of which is incorporated herein by reference. An application  
29 for the Trademark "Universal Completion Device™" was filed on  
30 July 24, 2001 that is Serial Number 76/293175, an entire copy  
31 of which is incorporated herein by reference. An application  
32 for the Trademark "Downhole BOP" was filed on August 17, 2001  
33 that is Serial Number 76/305201, an entire copy of which is  
34 incorporated herein by reference.

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1           Accordingly, in view of the Trademark Applications, the  
2 term "smart shuttle" will be capitalized as "Smart Shuttle";  
3 the term "well locomotive" will be capitalized as "Well  
4 Locomotive"; the term "downhole rig" will be capitalized as  
5 "Downhole Rig"; the term "universal completion device" will  
6 be capitalized as "Universal Completion Device"; and the term  
7 "downhole bop" will be capitalized as "Downhole BOP".  
8  
9

## 10                               BACKGROUND OF THE INVENTION 11 12

### 13       1.    Field of Invention 14

15           The fundamental field of the invention relates  
16 to methods and apparatus that may be used to drill and  
17 complete wells at great lateral distances from a  
18 drill site. The invention may be used to reach any lateral  
19 distance from the surface drill site, from close to the  
20 drill site, to a maximum radial distance of at least 20 miles  
21 from the surface drill site. This is accomplished by using a  
22 near neutrally buoyant umbilical that is attached to a  
23 subterranean electric drilling machine. The near  
24 neutrally buoyant umbilical is capable of providing up to  
25 320 horsepower to do work at lateral distances of at least  
26 20 miles. This drilling application requires near neutrally  
27 buoyant umbilicals capable of providing high power at great  
28 distances and high speed data communications to and from the  
29 surface. The near neutrally buoyant umbilical reduces the  
30 frictional drag of the umbilical within the wellbore. To  
31 convey drilling equipment to great distances also requires  
32 methods and apparatus to move heavy equipment through pipes  
33 at relatively high speeds. Similar high power umbilicals  
34 having high speed data communications to and from the surface

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1 are also useful for providing power and communications to  
2 remotely operated vehicles used for subsea service work in  
3 the oil and gas industry.  
4

5 Such high power electrically heated composite umbilicals  
6 are also useful as immersion heaters to be installed, or  
7 retrofitted, into subsea flowlines to prevent the formation  
8 of waxes and hydrates and to prevent the blockage of the  
9 flowlines. Such retrofitted electrically heated composite  
10 umbilicals provide an alternative for previously installed,  
11 but failed, permanent heating systems. A hydraulic pump  
12 installed on the distant end of an electrically heated  
13 composite umbilical also provides artificial lift to the  
14 produced hydrocarbons. Other electrically heated umbilicals  
15 used as immersion heaters are also described. Such immersion  
16 heater systems may be removed from the well, repaired, and  
17 retrofitted into flowlines without removing the flowlines.  
18 Near neutrally buoyant electrically heated umbilicals are  
19 described which may be installed great distances into  
20 flowlines. Different methods of deploying the electrically  
21 heated umbilicals are also discussed.  
22  
23

## 24 2. Description of the Related Art

25

26 The oil and gas industry does not now have the  
27 capability to drill horizontally extreme distances of  
28 approximately 20 miles to commercially meet some of the  
29 challenges that exist today. Industry extended  
30 reach-drilling capability is currently between 6 and 7 miles.  
31 Conventional drilling rigs using drill pipe and mud motors at  
32 shallow angles have established these conventional records.  
33 These wells have pushed conventional drilling technologies  
34

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1 close to their practical limit and new methods are required  
2 for longer offsets.

3  
4 The industry's lack of a 20 mile drilling capability  
5 reduces accessibility to oil and gas reserves. Many areas,  
6 both onshore and offshore, have no surface access for  
7 development drilling. Onshore, this may be due to urban  
8 development as is the case in Holland, national parks or  
9 other special areas such as the Arctic National Wildlife  
10 Refuge (ANWR), or other land uses that are sensitive to  
11 surface drilling operations. Offshore, the incentive is to  
12 maximize the use of existing structures and infrastructure by  
13 replacing expensive flowlines, manifold and trees. Near  
14 shore regions as found in the Santa Barbara Channel, and  
15 especially where ice may be present such as in the Arctic or  
16 near Sakhalin Island, or where migrating whales may limit  
17 seasonal operations provide significant incentives for this  
18 new 20 mile drilling capability.

19  
20 The industry does not have an extreme reach lateral  
21 drilling system that is compatible with existing drilling and  
22 production infrastructure. If such a system were available,  
23 new roads, drill sites, pits, site remediation, permitting,  
24 etc. are all avoided in such onshore operations. Offshore,  
25 existing host structures will have greatly extended  
26 usefulness while reservoirs within 20-mile radii may be  
27 developed.

28  
29 The industry does not have an extreme reach drilling  
30 capability that reduces the risk to the environment. If such  
31 a system were available, then operating from drilling and  
32 production centers would allow using subsurface access to the  
33 reservoirs. There would be no surface flowlines or  
34 facilities outside the regional drilling and production

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1 center. Extreme reach lateral drilling systems could  
2 eliminate the need for many of the flowlines on the ocean  
3 bottom in a regional development. However, centralized  
4 surface operations with fixed facilities require a paradigm  
5 shift in development drilling operations. The well drilling  
6 and maintenance equipment would not normally be mobile  
7 (except offshore on vessels) and it would normally spend its  
8 entire working life from one location.

9  
10 Several references are cited below related to the topics  
11 of expandable casing, methods to expand tubulars and casings,  
12 fabricating composite umbilicals, and well management  
13 systems.

14  
15 Relevant references to expandable casing includes  
16 U.S. Patent No. 5,667,011, entitled "Method of Creating a  
17 Casing in a Borehole", which issued on September 16, 1997,  
18 that is assigned to Shell Oil Company of Houston, Texas,  
19 and the following U.S. Patents, entire copies of which are  
20 incorporated herein by reference:

21  
22 U.S. 5,366,012; U.S. 5,348,095; U.S. 5,240,074;  
23 U.S. 4,716,965; U.S. 4,501,327; U.S. 4,495,997;  
24 U.S. 3,958,637; U.S. 3,203,451; U.S. 3,172,618;  
25 U.S. 3,052,298; U.S. 2,447,629; U.S. 2,207,478

26  
27  
28 Relevant references to expandable casing also includes  
29 U.S. Patent No. 6,431,282, entitled "Method for Annular  
30 Sealing", which issued on August 13, 2002, that is assigned  
31 to Shell Oil Company of Houston, Texas, and the following  
32 U.S. Patents, entire copies of which are incorporated  
33 herein by reference:

34  
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1 U.S. 6,012,522; U.S. 5,964,288; U.S. 5,875,845;  
2 U.S. 5,833,001; U.S. 5,794,702; U.S. 5,787,984;  
3 U.S. 5,718,288; U.S. 5,667,011; U.S. 5,337,823;  
4 U.S. 3,782,466; U.S. 3,489,220; U.S. 3,363,301;  
5 U.S. 3,297,092; U.S. 3,191,680; U.S. 3,134,442;  
6 U.S. 3,126,959; U.S. 2,294,294; U.S. 2,248,028  
7  
8

9 Other relevant foreign patent documents related  
10 expandable casing include the following, entire copies of  
11 which are incorporated herein by reference:  
12

13 E.P. 0,643,794; W.O. 09,933,763; W.O. 09,923,046;  
14 W.O. 09,906,670; W.O. 09,902,818; W.O. 09,703,489;  
15 W.O. 09,519,942; W.O. 09,419,574; W.O. 09,409,252;  
16 W.O. 09,409,250; W.O. 09,409,249  
17  
18

19 Other publications related to expandable casing include  
20 the following documents related to Enventure Global  
21 Technology of Houston, Texas, entire copies of which are  
22 incorporated herein by reference:  
23

24 (a) Campo, D., et al., "Drilling and Recompletion  
25 Applications Using Solid Expandable Tubular Technology",  
26 SPE/IADC 72304 at 2002 SPE/IADC Middle East Drilling  
27 Technology Conference and Exhibition, 11 March 2002.  
28

29 (b) Moore, M., et al., "Field Trial Proves Upgrades to Solid  
30 Expandable Tubulars", OTC 14217 at 2002 Offshore Technology  
31 Conference, 6-9 May 2002.  
32  
33  
34

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1 (c) Grant, T., et al., "Deepwater Expandable Openhole Liner  
2 Case Histories: Learnings Through Field Applications", OTC  
3 14218 at 2002 Offshore Technology Conference, 6-9 May 2002.

4  
5 (d) Dupal, K., et al., "Realization of the Mono-Diameter  
6 Well: Evolution of a Game-Changing Technology", OTC 14312 at  
7 2002 Offshore Technology Conference, 6-9 May 2002.

8  
9 (e) Moore, M., et al., "Expandable Linear Hangers: Case  
10 Histories", OTC 14313 at 2002 Offshore Technology Conference,  
11 6-9 May 2002.

12  
13 (f) Nor, N., et al., "Transforming Conventional Wells to  
14 Bigbore Completions Using Solid Expandable Tubular  
15 Technology", OTC 14315 at 2002 Offshore Technology  
16 Conference, 6-9 May 2002.

17  
18 (g) Merritt, R., et al., "Well Remediation Using Expandable  
19 Cased-Hole Liners - Summary of Case Histories", Texas Tech  
20 University's Southwestern Petroleum Short Course - 2002  
21 Conference.

22  
23 (h) Cales, G., et al., "Subsidence Remediation - Extending  
24 Well Life Through the Use of Solid Expandable Casing  
25 Systems", AADE 01-NC-HO-24 at March 2001 Conference.

26  
27 (i) Dupal, K., et al., "Solid Expandable Tubular  
28 Technology - A Year of Case Histories in the Drilling  
29 Environment", SPE/IADC 67770 at 2001 SPE/IADC Drilling  
30 Conference 27 February - 1 March 2001.

31  
32 (j) Dupal, K., et al., "Well Design With Expandable Tubulars  
33 Reduces Costs and Increases Success in Deepwater  
34 Applications", Deep Offshore Technology, 2002.

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1 (k) Daigle, C., et al., "Expandable Tubulars: Field Examples  
2 of Application in Well Construction and Remediation", SPE  
3 62958 at SPE Annual Technical Conference and Exhibition, 1-4  
4 October 2000.

5  
6 (l) Bullock, M., et al., "Using Expandable Solid Tubulars to  
7 Solve Well Construction Challenges in Deep Waters and  
8 Maturing Properties", IBP 275 00 at the Rio Oil & Gas  
9 Conference, 16-19 October 2000.

10  
11 (m) Mack, A., et al., "In-Situ Expansion of Casing and  
12 Tubing - Effect on Mechanical Properties and Resistance to  
13 Sulfide Stress Cracking", NACE 00164 at the NACE Expo  
14 Corrosion 2000 Conference, 26-30 March 2000.

15  
16 (n) Lohoefer, C., et al., "Expandable Liner Hanger Provides  
17 Cost-Effective Alternative Solution", IADC/SPE 59151 at 2000  
18 IADC/SPE Drilling Conference, 23-25 February 2000.

19  
20 (o) Filippov, A., et al., "Expandable Tubular Solutions",  
21 SPE 56500 at 1999 SPE Annual Technical Conference and  
22 Exhibition, 3-6 October 1999.

23  
24 (p) Haut, R., et al., "Meeting Economic Challenge of  
25 Deepwater Drilling with Expandable-Tubular Technology", Deep  
26 Offshore Technology Conference, 1999.

27  
28 (q) Bayfield, M., et al., "Burst and Collapse of a Sealed  
29 Multilateral Junction: Numerical Simulations", SPE/IADC 52873  
30 at 1999 SPE/IADC Drilling Conference, 9-11 March 1999.

31  
32  
33 Relevant references related to expandable casing also  
34 include U.S. Patent No. 6,354,373, entitled "Expandable

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1     Tubing for a Well Bore Hole and Method of Expanding", which  
2     issued on March 12, 2002, that is assigned to the  
3     Schlumberger Technology Corporation of Houston, Texas, and  
4     the following U.S. Patents, entire copies of which are  
5     incorporated herein by reference:

6  
7     U.S. 6,012,522; U.S. 5,631,557; U.S. 5,494,106;  
8     U.S. 5,366,012; U.S. 5,348,095; U.S. 5,337,823;  
9     U.S. 5,200,072; U.S. 5,083,608; U.S. 5,014,779;  
10    U.S. 4,976,322, U.S. 5,830,109; U.S. 4,716,965;  
11    U.S. 4,501,327; U.S. 4,495,997; U.S. 4,308,736;  
12    U.S. 3,948,321; U.S. 3,785,193; U.S. 3,691,624;  
13    U.S. 3,489,220; U.S. 3,477,506; U.S. 3,364,993;  
14    U.S. 3,353,599; U.S. 3,326,293; U.S. 3,054,455;  
15    U.S. 3,028,915; U.S. 2,734,580; U.S. 2,447,629;  
16    U.S. 2,214,226; U.S. 1,652,650; U.S. 341,327

17  
18  
19         Other relevant foreign patent documents related to  
20     expandable casing include the following, entire copies of  
21     which are incorporated herein by reference:

22  
23     S.U. 1,747,673; S.U. 1,051,222; W.O. 93/25799  
24  
25

26         Relevant references for methods to expand tubulars and  
27     casings include U.S. Patent No. 6,325,148, entitled "Tools  
28     and Methods for Use with Expandable Tubulars", which issued  
29     on December 4, 2001, that is assigned to Weatherford/Lamb,  
30     Inc. of Houston, Texas, and the following U.S. Patents,  
31     entire copies of which are incorporated herein by reference:

32  
33     U.S. 6,070,671; U.S. 6,029,748; U.S. 5,979,571;  
34     U.S. 5,960,895; U.S. 5,924,745; U.S. 5,901,789;

**"HIGH POWER UMBILICALS FOR  
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1 U.S. 5,887,668; U.S. 5,785,120; U.S. 5,706,905;  
2 U.S. 5,667,011; U.S. 5,636,661; U.S. 5,560,426;  
3 U.S. 5,553,679; U.S. 5,520,255; U.S. 5,472,057;  
4 U.S. 5,409,059; U.S. 5,366,012; U.S. 5,348,095;  
5 U.S. 5,322,127; U.S. 5,307,879; U.S. 5,301,760;  
6 U.S. 5,271,472; U.S. 5,267,613; U.S. 5,156,209;  
7 U.S. 5,052,849; U.S. 5,052,483; U.S. 5,014,779;  
8 U.S. 4,997,320; U.S. 4,976,322; U.S. 4,883,121;  
9 U.S. 4,866,966; U.S. 4,848,469; U.S. 4,807,704;  
10 U.S. 4,626,129; U.S. 4,581,617; U.S. 4,567,631;  
11 U.S. 4,505,612; U.S. 4,505,142; U.S. 4,502,308;  
12 U.S. 4,487,630; U.S. 4,483,399; U.S. 4,470,280;  
13 U.S. 4,450,612; U.S. 4,445,201; U.S. 4,414,739;  
14 U.S. 4,407,150; U.S. 4,387,502; U.S. 4,382,379;  
15 U.S. 4,362,324; U.S. 4,359,889; U.S. 4,349,050;  
16 U.S. 4,319,393; U.S. 3,977,076; U.S. 3,948,321;  
17 U.S. 3,820,370; U.S. 3,785,193; U.S. 3,780,562;  
18 U.S. 3,776,307; U.S. 3,746,091; U.S. 3,712,376;  
19 U.S. 3,691,624; U.S. 3,689,113; U.S. 3,669,190;  
20 U.S. 3,583,200; U.S. 3,489,220; U.S. 3,477,506;  
21 U.S. 3,354,955; U.S. 3,353,599; U.S. 3,326,293;  
22 U.S. 3,297,092; U.S. 3,245,471; U.S. 3,203,483;  
23 U.S. 3,203,451; U.S. 3,195,646; U.S. 3,191,680;  
24 U.S. 3,191,677; U.S. 3,186,485; U.S. 3,179,168;  
25 U.S. 3,167,122; U.S. 3,039,530; U.S. 3,028,915;  
26 U.S. 2,633,374; U.S. 2,627,891; U.S. 2,519,116;  
27 U.S. 2,499,630; U.S. 2,424,878; U.S. 2,383,214;  
28 U.S. 2,214,226; U.S. 2,017,451; U.S. 1,981,525;  
29 U.S. 1,880,218; U.S. 1,301,285; U.S. 988,504

30

31

32 Other relevant foreign patent documents related to  
33 methods to expand tubulars and casings include the following,  
34 entire copies of which are incorporated herein by reference:

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1 W.O. 99/23354; W.O. 99/18328; W.O. 99/02818; W.O. 98/00626;  
2 W.O. 97/21901; W.O. 94/25655; W.O. 93/24728; W.O. 92/01139  
3 G.B. 2329918A; G.B. 2320734A; G.B. 2313860B; G.B. 2216926A;  
4 G.B. 1582392; G.B. 1457843; G.B. 1448304; G.B. 1277461;  
5 G.B. 997721; G.B. 792886; G.B. 730338;  
6 E.P. 0 961 007 A2; E.P. 0 952 305 A1; E.P. WO93/25800;  
7 D.E. 4133802C1; D.E. 3213464A1  
8  
9

10 Another relevant publication related to methods to  
11 expand tubulars and casings includes the following, an entire  
12 copy of which is incorporated herein by reference:  
13

14 Metcalfe, P. "Expandable Slotted Tubes Offer Well Design  
15 Benefits", Petroleum Engineer International, vol. 69, No. 10  
16 (Oct 1996), pp 60-63.  
17  
18

19 Relevant references for fabricating composite umbilicals  
20 includes U.S. Patent No. 6,357,485, entitled "Composite  
21 Spoolable Tube", which issued on March 19, 2002, that is  
22 assigned to the Fiberspar Corporation, and the following  
23 U.S. Patents, entire copies of which are incorporated herein  
24 by reference:  
25

26 U.S. 6,286,558; U.S. 6,148,866; U.S. 5,921,285;  
27 U.S. 6,016,845; U.S. 646,887; U.S. 1,930,285;  
28 U.S. 2,648,720; U.S. 2,690,769; U.S. 2,725,713;  
29 U.S. 2,810,424; U.S. 3,116,760; U.S. 3,277,231;  
30 U.S. 3,334,663; U.S. 3,379,220; U.S. 3,477,474;  
31 U.S. 3,507,412; U.S. 3,522,413; U.S. 3,554,284;  
32 U.S. 3,579,402; U.S. 3,604,461; U.S. 3,606,402;  
33 U.S. 3,692,601; U.S. 3,700,519; U.S. 3,701,489;  
34 U.S. 3,734,421; U.S. 3,738,637; U.S. 3,740,285;

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1 U.S. 3,769,127; U.S. 3,783,060; U.S. 3,828,112;  
2 U.S. 3,856,052; U.S. 3,856,052; U.S. 3,860,742;  
3 U.S. 3,933,180; U.S. 3,956,051; U.S. 3,957,410;  
4 U.S. 3,960,629; U.S. RE29,122; U.S. 4,053,343;  
5 U.S. 4,057,610; U.S. 4,095,865; U.S. 4,108,701;  
6 U.S. 4,125,423; U.S. 4,133,972; U.S. 4,137,949;  
7 U.S. 4,139,025; U.S. 4,190,088; U.S. 4,200,126;  
8 U.S. 4,220,381; U.S. 4,241,763; U.S. 4,248,062;  
9 U.S. 4,261,390; U.S. 4,303,457; U.S. 4,308,999;  
10 U.S. 4,336,415; U.S. 4,463,779; U.S. 4,515,737;  
11 U.S. 4,522,235; U.S. 4,530,379; U.S. 4,556,340;  
12 U.S. 4,578,675; U.S. 4,627,472; U.S. 4,657,795;  
13 U.S. 4,681,169; U.S. 4,728,224; U.S. 4,789,007;  
14 U.S. 4,992,787; U.S. 5,097,870; U.S. 5,170,011;  
15 U.S. 5,172,765; U.S. 5,176,180; U.S. 5,184,682;  
16 U.S. 5,209,136; U.S. 5,285,008; U.S. 5,285,204;  
17 U.S. 5,330,807; U.S. 5,334,801; U.S. 5,348,096;  
18 U.S. 5,351,752; U.S. 5,428,706; U.S. 5,435,867;  
19 U.S. 5,443,099; U.S. RE35,081; U.S. 5,469,916;  
20 U.S. 5,551,484; U.S. 5,730,188; U.S. 5,755,266;  
21 U.S. 5,828,003; U.S. 5,921,285; U.S. 5,933,945;  
22 U.S. 5,951,812; U.S. 6,016,845; U.S. 6,148,866;  
23 U.S. 6,286,558; U.S. 6,004,639; U.S. 6,361,299  
24  
25

26 Other relevant foreign patent documents related to  
27 fabricating composite umbilicals include the following,  
28 entire copies of which are incorporated herein  
29 by reference:  
30

31 DE 4214383; EP 0024512; EP 352148; EP 505815; GB 553,110;  
32 GB 2255994; GB 2270099  
33  
34

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1           Other relevant publications related to fabricating  
2 composite umbilicals include the following, entire copies of  
3 which are incorporated herein by reference:  
4

5       (a) Fowler Hampton et al.; "Advanced Composite Tubing  
6 Usable", The American Oil & Gas Reporter, pp. 76-81  
7 (Sep. 1997).  
8

9       (b) Fowler Hampton et al.; "Development Update and  
10 Applications of an Advanced Composite Spoolable Tubing",  
11 Offshore Technology Conference held in Houston Texas from  
12 4th to 7th of May 1998, pp. 157-162.  
13

14       (c) Hahan H. Thomas and Williams G. Jerry; "Compression  
15 Failure Mechanisms in Unidirectional Composites", NASA  
16 Technical Memorandum pp 1-42 (Aug. 1984).  
17

18       (d) Hansen et al.; "Qualification and Verification of  
19 Spoolable High Pressure Composite Service Lines for the  
20 Asgard Field Development Project", paper presented at the  
21 1997 Offshore Technology Conference held in Houston Texas  
22 from 5th to 8th of May 1997, pp. 45-54.  
23

24       (e) Haug et al.,; "Dynamic Umbilical with Composite Tube  
25 (DUCT)", Paper presented at the 1998 Offshore Technology  
26 Conference held in Houston Texas from 4th to 7th of May,  
27 1998, pp.699-712.  
28

29       (f) Lundberg et al.; "Spin-off Technologies from Development  
30 of Continuous Composite Tubing Manufacturing Process", Paper  
31 presented at the 1998 Offshore Technology Conference held in  
32 Houston, Texas from 4th to 7th of May 1998, pp. 149-155.  
33  
34

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1 (g) Marker et al.; "Anaconda: Joint Development Project  
2 Leads to Digitally Controlled Composite Coiled Tubing  
3 Drilling System", Paper presented at the SPEI/COTA, Coiled  
4 Tubing Roundtable held in Houston, Texas from 5th to 6th of  
5 Apr., 2000, pp. 1-9.

6  
7 (h) Measures R.M.; "Smart Structures with Nerves of Glass",  
8 Prog. Aerospace Sc. 26(4):289-351 (1989).

9  
10 (i) Measures et al.; "Fiber Optic Sensors for Smart  
11 Structures", Optics and Lasers Engineering 16: 127-152 (1992)

12  
13 (j) Poper Peter; "Braiding", International Encyclopedia of  
14 Composites, Published by VGH, Publishers, Inc., 220 English  
15 23rd Street, Suite 909, New York, NY 10010.

16  
17 (k) Quigley et al., "Development and Application of a Novel  
18 Coiled Tubing String for Concentric Workover Services", Paper  
19 presented at the 1997 Offshore Technology Conference held in  
20 Houston, Texas from 5th to 8th of May 1997, pp. 189-202.

21  
22 (l) Sas-Jaworsky II and Bell Steve "Innovative Applications  
23 Stimulated Coiled Tubing Development", World Oil, 217(6): 61  
24 (Jun. 1996).

25  
26 (m) Sas-Jaworsky II and Mark Elliot Teel; "Coiled Tubing  
27 1995 Update: Production Applications", World Oil, 216 (6): 97  
28 (Ju. 1995).

29  
30 (n) Sas-Jaworsky, A. and J.G. Williams, "Advanced composites  
31 enhance coiled tubing capabilities", World Oil, pp. 57-69  
32 (Apr. 1994).

33  
34  
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1 (o) Sas-Jaworsky, A. and J.G. Williams, "Development of a  
2 composite coiled tubing for oilfield services", Society of  
3 Petroleum Engineers, SPE 26536, pp. 1-11 (1993).

4  
5 (p) Sas-Jaworsky, A. and J.G. Williams, "Enabling  
6 capabilities and potential application of composite coiled  
7 tubing", Proceedings of World Oil's 2nd International  
8 Conference on Coiled Tubing Technology, pp. 2-9 (1994).

9  
10 (p) Sas-Jaworsky II Alex; "Developments Position CT for  
11 Future Prominence", The American Oil & Gas Reporter, pp. 87-  
12 92 (Mar. 1996).

13  
14 (r) Moe Wood T., et al.; "Spoolable, Composite Tubing for  
15 Chemical and Water Injection and Hydraulic Valve Operation",  
16 Proceedings of the 11th International Conference on Offshore  
17 Mechanics and Arctic Engineering-1992, vol. III, Part A-  
18 Materials Engineering, pp. 199-207 (1992).

19  
20 (s) Shuart J.M. et al.; "Compression Behavior of 45°-  
21 Dominated Laminates with a Circular Hole of Impact Damage",  
22 AIAA Journal 24(1): 115-122 (Jan. 1986).

23  
24 (t) Silverman A. Seth, "Spoolable Composite Pipe for  
25 Offshore Applications", Materials Selection & Design pp. 48-  
26 50 (Jan. 1997).

27  
28 (u) Rispler K. et al.; "Composite Coiled Tubing in Harsh  
29 Completion/Workover Environments", paper presented at the SPE  
30 Gas Technology Symposium and Exhibition held in Calgary,  
31 Alberta, Canada, on Mar. 15-18, 1998, pp. 405-410.

32  
33 (v) Williams G.J. et al.; "Composite Spoolable Pipe  
34 Development, Advancements, and Limitations", Paper presented

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1 at the 2000 Offshore Technology Conference held in Houston  
2 Texas from 1st to 4th of May 2000, pp. 1-16.

3  
4  
5 A relevant reference for well management systems  
6 includes U.S. Patent No. 6,257,332, entitled "Well Management  
7 System", which issued on July 10, 2001, that is assigned to  
8 the Halliburton Energy Services, Inc., an entire copy of  
9 which incorporated herein by reference.

10  
11 Typical procedures used in the oil and gas industries to  
12 drill and complete wells are well documented. For example,  
13 such procedures are documented in the entire "Rotary Drilling  
14 Series" published by the Petroleum Extension Service of The  
15 University of Texas at Austin, Austin, Texas that is  
16 incorporated herein by reference in its entirety  
17 comprised of the following:

18 Unit I - "The Rig and Its Maintenance" (12 Lessons);  
19 Unit II - "Normal Drilling Operations" (5 Lessons);  
20 Unit III - Nonroutine Rig Operations (4 Lessons);  
21 Unit IV - Man Management and Rig Management (1 Lesson);  
22 and Unit V - Offshore Technology (9 Lessons). All of the  
23 individual Glossaries of all of the above Lessons in their  
24 entirety are also explicitly incorporated herein, and all  
25 definitions in those Glossaries shall be considered to  
26 be explicitly referenced and/or defined herein.

27  
28 Additional procedures used in the oil and gas industries  
29 to drill and complete wells are well documented in the series  
30 entitled "Lessons in Well Servicing and Workover" published  
31 by the Petroleum Extension Service of The University of Texas  
32 at Austin, Austin, Texas that is incorporated herein by  
33 reference in its entirety comprised of all 12 Lessons. All  
34 of the individual Glossaries of all of the above Lessons in

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1 their entirety are also explicitly incorporated herein, and  
2 any and all definitions in those Glossaries shall be  
3 considered to be explicitly referenced and/or defined herein.  
4

5 Entire copies of each and every reference explicitly  
6 cited above in this section entitled "Description of the  
7 Related Art" are incorporated herein by reference.  
8

9 At the time of the filing of the application herein,  
10 the applicant is unaware of any additional art that is  
11 particularly relevant to the invention other than that cited  
12 in the above defined "related" U.S. Patents, the "related"  
13 co-pending U.S. Patent Applications, the "related" co-pending  
14 PCT Application, and the "related" U.S. Disclosure Documents  
15 that are specified in the first paragraphs of this  
16 application.  
17  
18

#### 19 SUMMARY OF THE INVENTION 20

21 An object of the invention is to provide high power  
22 umbilicals for subterranean electric drilling.  
23

24 Another object of the invention is to provide high power  
25 umbilicals that allow subterranean electric drilling machines  
26 to drill boreholes of up to 20 miles laterally from surface  
27 drill sites.  
28

29 Another object of the invention is to provide high power  
30 umbilicals that allow the subterranean liner expansion tools  
31 to install casings within monobore wells to distances of up  
32 to 20 miles laterally from surface drill sites.  
33  
34

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1           Another object of the invention is to provide high power  
2 near neutrally buoyant umbilicals for subterranean electric  
3 drilling to reduce the frictional drag on the umbilicals.  
4

5           Yet another object of the invention is to provide a  
6 high power near neutrally buoyant umbilical that possesses  
7 high speed data communications and also provides a conduit  
8 for drilling mud.  
9

10          Another object of the invention is to provide an  
11 umbilical that delivers in excess of 60 kilowatts to a  
12 downhole electric motor that is a portion of a subterranean  
13 electric drilling machine.  
14

15          Yet another object of the invention is to provide a  
16 novel feedback control of a downhole electric motor that is a  
17 part of a subterranean electric drilling machine.  
18

19          Yet another object of the invention is to provide high  
20 power umbilicals to operate subsea remotely operated  
21 vehicles.  
22

23          Another object of the invention is to provide an  
24 umbilical to operate a subsea remotely operated vehicle that  
25 possesses high speed data communications and provides a  
26 conduit for fluids.  
27

28          Yet another object of the invention is to provide a  
29 novel feedback control of a downhole electric motor that  
30 comprises a portion of a remotely operated vehicle.  
31

32          Another object of the invention is to provide electric  
33 flowline immersion heater assemblies that may be retrofitted  
34 into existing subsea flowlines.

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1           Yet another object of the invention is to provide  
2 electrically heated composite umbilicals that may be  
3 retrofitted into existing subsea flowlines.  
4

5           Another object of the invention is to provide different  
6 types of electrically heated composite umbilicals that may be  
7 installed within subsea flowlines.  
8

9           Yet another object of the invention is to provide  
10 different types of electrically heated umbilicals.  
11

12           Another object of the invention is to provide different  
13 methods to convey electrically heated composite umbilicals  
14 into subsea flowlines.  
15

16           Yet another object of the invention is to provide  
17 different methods to convey electrically heated umbilicals  
18 into subsea flowlines.  
19

20           Another object of the invention is to provide  
21 electrically heated immersion heater systems to prevent the  
22 build up of wax and hydrates to prevent the blockage of  
23 subsea flowlines.  
24

25           Yet another object of the invention is to provide a  
26 hydraulic pump attached to the distant end of an electrically  
27 heated composite umbilical installed within a flowline to  
28 provide artificial lift to the produced hydrocarbons.  
29

30           Another object of the invention is to provide a  
31 hydraulic pump attached to the distant end of an electrically  
32 heated umbilical installed within a flowline to provide  
33 artificial lift to the produced hydrocarbons.  
34

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1           Yet another object of the invention is to install an  
2 electrically heated composite umbilical within a flowline  
3 carrying heavy oils to reduce the viscosity of those heavy  
4 oils.

5  
6           Another object of the invention is to provide  
7 electrically heated composite umbilicals that are heated  
8 uniformly within a flowline.

9  
10          Yet another object of the invention is to provide  
11 electrically heated composite umbilicals that are heated  
12 nonuniformly within a flowline.

13  
14          Yet another object of the invention is to provide  
15 electrically heated composite umbilicals that are  
16 substantially neutrally buoyant within the fluids present  
17 within the flowlines.

18  
19          Another object of the invention is to provide  
20 electrically heated umbilicals that are substantially  
21 neutrally buoyant within the fluids present within the  
22 flowlines.

23  
24          And finally, it is yet another object of the invention  
25 to provide an electrically heated immersion heater system that  
26 may be removed from the well, repaired, and retrofitted in  
27 the flowline without removing the flowline.

#### 28 29 30                   BRIEF DESCRIPTION OF THE DRAWINGS

31  
32          Figure 1 shows a section view of a umbilical that is  
33 substantially neutrally buoyant in drilling mud within the  
34 well which provides a conduit for drilling fluids that is

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1 capable of providing 320 horsepower of electrical power at a  
2 distance of up to 20 miles.

3  
4 Figure 2 shows the uphole and downhole power management  
5 system for the composite umbilical shown in Figure 1.

6  
7 Figure 3 shows an electrical block diagram representing  
8 two conductors from one three phase delta circuit providing  
9 up to 160 horsepower of electrical power at a distance of  
10 up to 20 miles.

11  
12 Figure 4 shows an umbilical carousel in the process of  
13 being constructed.

14  
15 Figure 5 shows a computerized uphole management system  
16 for the umbilical that provides for the closed-loop automatic  
17 control of all uphole and downhole functions.

18  
19 Figure 6 generally shows the subterranean electric  
20 drilling machine that is disposed within a previously  
21 installed borehole casing during the process of drilling a  
22 new borehole and simultaneously installing a section of  
23 expandable casing.

24  
25 Figure 7 shows the casing hanger.

26  
27 Figure 8 shows detail for a downhole pump motor assembly  
28 that is related to the downhole pump motor assembly in  
29 Figure 6.

30  
31 Figure 9 shows a subterranean electric drilling machine  
32 boring a new borehole from an offshore platform.

33  
34  
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1           Figure 10 shows a section view of the subterranean liner  
2 expansion tool positioned within an unexpanded casing that is  
3 injecting new cement into the new borehole.  
4

5           Figure 11 shows the subterranean liner expansion tool in  
6 the process of expanding the expandable casing within the new  
7 borehole before the new cement sets up.  
8

9           Figure 12 shows the casing hanger after a portion of it  
10 has been expanded with the casing hanger setting tool inside  
11 the previously installed casing.  
12

13           Figure 13 shows a section view of the monobore well, or  
14 near-monobore well, after passage of the subterranean liner  
15 expansion tool.  
16

17           Figure 14 shows relevant parameters related to fluid  
18 flow rates through the umbilical.  
19

20           Figure 15 shows various parameters related to tripping  
21 the subterranean electric drilling machine and the expandable  
22 casing into the well.  
23

24           Figure 16 shows a subterranean electric drilling machine  
25 boring a new borehole under the ocean bottom from an  
26 onshore wellsite.  
27

28           Figure 17 shows a subterranean electric drilling machine  
29 boring a new borehole under the earth from a land based  
30 drill site.  
31

32           Figure 18 shows an open hole subterranean electric  
33 drilling machine that is drilling an open borehole in the  
34 earth.

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1           Figure 19 shows screw drive subterranean electric  
2 drilling machine that is drilling an open borehole in  
3 the earth.  
4

5           Figure 20 shows a cross section of another embodiment of  
6 an umbilical used for subterranean electric drilling  
7 machines, for open hole subterranean electric drilling  
8 machines, and for other applications.  
9

10          Figure 21 shows yet another neutrally buoyant composite  
11 umbilical in 12 lb per gallon mud.  
12

13          Figure 22 shows an umbilical providing power in excess  
14 of 60 kilowatts and communications to a remotely operated  
15 vehicle  
16

17          Figure 23 shows a umbilical providing power in excess of  
18 60 kilowatts, communications, and fluids to a remotely  
19 operated vehicle.  
20

21          Figure 24 shows a sectional view of one preferred  
22 embodiment of a Smart Shuttle™.  
23

24          Figure 25 shows a sectional view of a tractor deployer  
25 operated from an umbilical.  
26

27          Figure 26 shows various devices that may be attached to  
28 the Retrieval Sub of the Smart Shuttle and the tractor  
29 conveyor.  
30

31          Figure 27 shows a diagrammatic representation of  
32 functions that may be performed with the Smart Shuttle and  
33 the tractor conveyance system.  
34

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1           Figure 28 shows a subsea well providing produced  
2 hydrocarbons to a fixed platform through several subsea  
3 flowlines.  
4

5           Figure 29 shows four subsea wells providing produced  
6 hydrocarbons to a Floating Production, Storage, and  
7 Offloading structure (FPSO) through four different subsea  
8 flowlines.  
9

10          Figure 30 shows an Electrically Heated Composite  
11 Umbilical ("EHCU") installed within a subsea flowline that is  
12 providing produced hydrocarbons to a floating platform that  
13 was conveyed into place using a particular method of  
14 conveyance.  
15

16          Figure 31 shows an embodiment of an Electric Flowline  
17 Immersion Heater Assembly ("EFIHA") having an Electrically  
18 Heated Composite Umbilical ("EHCU") in a subsea flowline that  
19 was conveyed into place using a Smart Shuttle that obtains  
20 its power from a wireline located within the EHCU.  
21

22          Figure 32 shows another embodiment of an Electric  
23 Flowline Immersion Heater Assembly ("EHCU") having an  
24 Electrically Heated Composite Umbilical in a subsea flowline  
25 that was conveyed into place using a Smart Shuttle that  
26 obtains its electrical power from additional electrical  
27 conductors within the EHCU.  
28

29          Figure 33 shows yet another embodiment of an Electric  
30 Flowline Immersion Heater Assembly ("EFIHA") having an  
31 Electrically Heated Composite Umbilical in a subsea flowline  
32 that was conveyed into place using particular methods of  
33 operation so that no fluid will be forced into the reservoir  
34 during transit of the EFIHA into the flowline.

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1           Figure 34 shows still another embodiment of an Electric  
2 Flowline Immersion Heater Assembly having an Electrically  
3 Heated Composite Umbilical in a subsea flowline that was  
4 conveyed into place using yet another method of conveyance.  
5

6           Figure 35 shows an Electrically Heated Composite  
7 Umbilical being installed within a flowline by a tractor  
8 means, where the host of the flowline is a floating platform.  
9

10          Figure 36 shows a Pump-Down Conveyed Flowline Immersion  
11 Heater Assembly ("PDCFIHA") possessing an Electrically Heated  
12 Composite Umbilical ("EHCU") installed within a flowline,  
13 where the host of the flowline is a Floating Production,  
14 Storage and Offloading ("FPSO") ship.  
15

16          Figure 37 shows a Pump-Down Conveyed Flowline Immersion  
17 Heater Assembly ("PDCFIHA") installed within a flowline,  
18 where the host of the flowline is a floating platform.  
19

20          Figure 37A shows a Pump-Down Conveyed Flowline Immersion  
21 Heater Assembly ("PDCFIHA") installed within a flowline to be  
22 used for artificial lift during hydrocarbon production, where  
23 the host of the flowline is a floating platform.  
24

25          Figure 38 shows an Electric Flowline Immersion Heater  
26 Assembly ("EFIHA") which possesses an Electrical Heated  
27 Composite Umbilical that is used to produce heavy oil from  
28 an open borehole that also uses a hydraulic pump for  
29 artificial lift.  
30

31          Figure 39 an exploratory well with large volume fluid  
32 sampling capability obtained from a downhole sampling unit.  
33  
34

1           Figure 40 shows an apparatus that provides electrical  
2 power from a flowline penetrating connector to other subsea  
3 systems.  
4

5           Figure 41 shows one embodiment of a composite umbilical  
6 used to uniformly heat a flowline.  
7

8           Figure 42 shows a first resistor network used to  
9 electrically heat a composite umbilical.  
10

11           Figure 43 shows an embodiment of a composite umbilical  
12 used to nonuniformly heat a flowline.  
13

14           Figure 44 shows an embodiment of a second resistor  
15 network used to nonuniformly heat a composite umbilical.  
16

17           Figure 45 shows an embodiment of an electrically heated  
18 umbilical that is surrounded with steel or synthetic armor.  
19

20           Figure 46 shows an embodiment of an electrically heated  
21 umbilical that possesses an electric cable as a heating  
22 element within a steel coiled tubing.  
23

24           Figure 47 shows another embodiment of an electrically  
25 heated umbilical that possesses an electric cable as a  
26 heating element within steel coiled tubing that is surrounded  
27 by thermal insulation.  
28

29           Figure 48 shows yet another embodiment of an  
30 electrically heated umbilical that is a bundled umbilical  
31 possessing electric cables and tubes capable of carrying  
32 fluids.  
33  
34

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## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a section view of a preferred embodiment of an umbilical 2. In this preferred embodiment, substantial portions of the umbilical are fabricated from one or more composite materials. Consequently umbilical 2 is also called a composite umbilical. Composite umbilical 2 provides a connection between the surface and other downhole tools (such as a subterranean electric drilling machine to be described later) which is capable of performing useful work at great distances from a well site. In the preferred embodiment shown in Figure 1, the umbilical is capable of performing useful work at the distance of 20 miles away from a surface drilling site. This statement means that the umbilical is capable of performing useful work at any distance between 0 miles to 20 miles away from a wellsite. This connection is called an umbilical and it does not rotate like drill pipe and its capabilities are different from those of coiled tubing used in drilling operations.

In particular, Figure 1 shows an umbilical that is substantially neutrally buoyant in any specific density of drilling mud 4 that is present in a wellbore. The drilling mud 4 may also be called the drilling fluid. The symbol for the density of drilling mud is  $\rho$ (drilling mud). In this particular example of a preferred embodiment, the density of drilling mud present in the wellbore is 12 lbs/gallon.

In Figure 1, the composite umbilical is partially fabricated from inside pipe 6. In Figure 1, the umbilical has an inside diameter of ID1. In this particular embodiment, the inside diameter ID1 is equal to 4.5 inches. The inside diameter forms a hollow region through which fluids may be sent to, and from downhole. Put another way,

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1 the inside diameter forms a conduit through which fluids may  
2 be sent from the surface downhole, or from downhole to the  
3 surface. Therefore, the umbilical possesses a fluid conduit  
4 for conducting drilling fluids through the interior of the  
5 umbilical. The fluids present within the inside pipe are  
6 shown by element 8 in Figure 1. The density of the  
7 fluids 8 is defined to be the symbol  $\rho$ (umbilical fluid).  
8 For example, drilling mud may be sent downhole through the  
9 4.5 inch ID pipe. The ID of this pipe is also called the  
10 interior of this pipe. The inside pipe 6 has wall thickness  
11 T1, but this legend is not shown in Figure 1 for brevity.  
12 In this preferred embodiment, the wall thickness of the  
13 inside pipe T1 is 0.25 inches. The wall of the inside  
14 pipe 6 is made from a composite material. This composite  
15 wall may have many layers of different composite materials  
16 made of different materials, each layer having a different  
17 specific gravity. As an example of one preferred embodiment,  
18 the composite material may be a carbon-based composite  
19 material. For reasons of simplicity, those layers are not  
20 shown in Figure 1. However, there will be an average  
21 specific gravity of the interior pipe that is defined to be  
22 SG(inside pipe). In this preferred embodiment, the specific  
23 gravity of the inside pipe is equal to 1.5.

24  
25 In Figure 1, the composite umbilical is partially  
26 fabricated from outside pipe 10. In Figure 1, the umbilical  
27 has an outside diameter of OD2 and this legend is shown in  
28 Figure 1. In this preferred embodiment, the outside diameter  
29 OD2 is equal to 6.00 inches O.D. Consequently, the external  
30 portion of the composite umbilical appears to be a pipe  
31 having the outside diameter of OD2. The outside pipe 10 has  
32 wall thickness T2, but this legend is not shown in  
33 Figure 1 for brevity. In this preferred embodiment, the wall  
34 thickness of the outside pipe T2 is 0.25 inches. The wall

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1 of the outside pipe 10 is made from a composite material.  
2 This composite wall may have many layers of different  
3 composite materials made of different materials, each layer  
4 having a different specific gravity. In one preferred  
5 embodiment, the composite material may be a carbon-based  
6 composite material. Those layers are not shown in Figure 1  
7 for simplicity. For example, an outer layer of composite  
8 material may be chosen to be particularly abrasion resistant.  
9 As one example, the outer layer of composite material may be  
10 made of a carbon-based composite material. However, there  
11 will be an average specific gravity of the outside pipe that  
12 is defined to be SG(outside pipe). In this preferred  
13 embodiment, the specific gravity of the outside pipe is equal  
14 to 1.5.

15  
16 As shown in Figure 1, the interior pipe 6 is  
17 asymmetrical located within the exterior pipe 10 that forms  
18 an the asymmetric volume 12 between the two pipes. Within  
19 the asymmetric volume 12 between the two pipes are insulated  
20 current carrying electric wires designated by the legends A,  
21 B, C, D, E, and F in Figure 1. Also shown in Figure 1 is  
22 high speed data link 14. This high speed data link provides  
23 high speed data communications from the surface to downhole  
24 equipment, and from the downhole equipment to the surface.  
25 High speed data link 14 is selected from a list including a  
26 fiber optic cable, a coaxial cable, and twisted wire cables.  
27 In the particular preferred embodiment of the invention shown  
28 in Figure 1, the high speed data link is chosen to be a fiber  
29 optic cable. The asymmetric volume 12 between the two pipes  
30 that contains wires A, B, C, D, E, and F, and the fiber optic  
31 cable, is otherwise filled with syntactic foam material.  
32 This syntactic foam material is often made from silica  
33 microspheres that are embedded in a filler material, such as  
34 epoxy resin or other composite materials. The syntactic foam

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1 material has a specific gravity that is defined as  
2 SG(syntactic foam material). In this preferred embodiment of  
3 the invention, the specific gravity of the syntactic foam  
4 material is 0.825. In this preferred embodiment of the  
5 invention, syntactic foam material possessing silica  
6 microspheres is provided by the Cumming Corporation. The  
7 Cumming Corporation is located at 225 Bodwell Street, Avon,  
8 MA 02322. The Cumming Corporation can also be reached by  
9 telephone at (508) 580-2660 or by the internet at  
10 www.emersoncumming.com. The details on the syntactic foam  
11 material may be reviewed in detail in Attachment 28 to  
12 Provisional Patent Application Number 60/384,964, that has  
13 the Filing Date of June 3, 2002, an entire copy of which is  
14 incorporated herein by reference. Using silica microspheres  
15 in a syntactic matrix provides the necessary buoyancy in high  
16 pressure wellbores. The high axial strength of the composite  
17 pipe construction compensates for variations in axial loads  
18 caused by mud weight and other density variations.

19  
20 In Figure 1, wires A, B, C, D, E, and F are 0.355 inches  
21 O.D. insulated No. 4 AWG Wire. The insulation is rated at  
22 14,000 volts DC, or 0-peak AC. Wires A, B, and C comprise  
23 the first independent three phase delta circuit. Wires D, E,  
24 and F comprise the second independent three phase delta  
25 circuit. Each separate circuit is capable of providing 160  
26 horsepower (119 kilowatts) over an umbilical length of 20  
27 miles at the temperature of 150 degrees C. So, combined,  
28 the umbilical can deliver a total of 320 horsepower  
29 (238 kilowatts) at 20 miles to do work at that distance.  
30 At 320 horsepower, less than 1 watt per foot of power is  
31 dissipated in the form of heat, which makes this a practical  
32 design even if the umbilical is completely wound up on an  
33 umbilical carousel as shown in a later figure (Figure 4). In  
34 this preferred embodiment, wires A, B, C, D, E, and F are

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1 No. 4 AWG stranded silver plated copper wire which are  
2 covered with insulation rated to 14,000 VDC at 200 degrees C,  
3 where each wire has a DC resistance of 0.250 ohms per 1000  
4 feet at the temperature of 20 degrees C, where the nominal  
5 outside diameter of each insulated wire is 0.355 inches, and  
6 where each wire weighs 180 lbs/1000 feet. Each wire is Part  
7 Number FEP4FLEXSC provided by Allied Wire & Cable, Inc. which  
8 is located at 401 East 4th Street, Bridgeport, PA 19405,  
9 which may be reached by telephone at (800) 828-9473. The  
10 details on Allied Part Number FEP4FLEXSC may be reviewed in  
11 Attachment 27 to Provisional Patent Application Number  
12 60/384,964, that has the Filing Date of June 3, 2002, an  
13 entire copy of which is incorporated herein by reference.  
14

15 If the inside pipe 6 is carrying 12 lb per gallon mud,  
16 and if the exterior pipe is immersed in 12 lb per gallon mud  
17 in the well, then the upward buoyant force in the above  
18 preferred embodiment of the umbilical is plus 5.9 lbs per  
19 1000 feet of this umbilical. Assuming a coefficient of  
20 friction of 0.2, the total frictional "pull-back" on 20 miles  
21 of this umbilical is only 124 lbs. This "pull-back" does not  
22 include any differential fluid drag forces. This umbilical  
23 was chosen to have an extreme length which shows that the  
24 essentially neutrally buoyant umbilical overcomes most  
25 friction problems associated with umbilicals disposed in  
26 wells. For the details of this calculation of a net upward  
27 force of 5.9 lbs as described above, please refer to "Case J"  
28 of Attachment 34 to Provisional Patent Application Number  
29 60/384,964, that has the Filing Date of June 3, 2002, an  
30 entire copy of which is incorporated herein by reference.  
31 Those particular calculations were performed on the date of  
32 November 12, 2001. In these calculations, the density of  
33 water of 62.43 lbs/cubic foot was used to calculate the net  
34 forces acting on volumes having particular specific

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1 gravities. Please also see other relevant buoyancy  
2 calculations in Attachments 29 to 35 of Provisional Patent  
3 Application Number 60/384,964.

4  
5 The phrase "substantially neutrally buoyant",  
6 "essentially neutrally buoyant", "near neutral buoyant", and  
7 "approximately neutrally buoyant" may be used  
8 interchangeably. For a substantially neutrally buoyant  
9 umbilical, or near neutrally buoyant umbilical, the downward  
10 force of gravity on a section of the umbilical of a given  
11 length is approximately balanced out by the upward buoyant  
12 force of well fluid acting on the umbilical of that given  
13 length. The density of mud in the well is strongly  
14 influenced by any cuttings from any drilling machine attached  
15 to the umbilical (to be described later). Similarly, the  
16 density of the fluids inside pipe 6 may also be strongly  
17 influenced by any cuttings from the drilling machine  
18 (if reverse flow is used). So, the density of the drilling  
19 mud 4 and the density of fluids present within the pipe 8 may  
20 vary with distance along the length of the umbilical.  
21 However, at any position along the length of the umbilical  
22 which is disposed in the well, the umbilical may be designed  
23 to be "substantially neutrally buoyant", "essentially  
24 neutrally buoyant", "near neutral buoyant" or "approximately  
25 neutrally buoyant". In addition, using the design principles  
26 described herein, the entire length of the umbilical may be  
27 designed to be on average "substantially neutrally buoyant",  
28 "essentially neutrally buoyant", "near neutral buoyant", or  
29 "approximately neutrally buoyant" over the entire length of  
30 the umbilical that is disposed within a wellbore.

31  
32 An umbilical that is "substantially neutrally buoyant",  
33 "essentially neutrally buoyant", "near neutral buoyant", or  
34 "approximately neutrally buoyant" greatly reduces the

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1 frictional drag on the umbilical as it moves in the wellbore.  
2 That statement is evident from the following. The net  
3 force on a length of umbilical from gravity and buoyant  
4 forces is F. The coefficient of sliding friction is k.  
5 Therefore, the net "pull back force" P for the given length  
6 of the umbilical is given by:

$$P = F k \quad \text{Equation 1.}$$

9  
10 The requirement of a near neutrally buoyant umbilical  
11 greatly reduces the frictional drag on the umbilical as it  
12 moves in the wellbore. This is a particularly important  
13 point. If an umbilical is "substantially neutrally buoyant",  
14 "essentially neutrally buoyant", "near neutral buoyant", or  
15 "approximately neutrally buoyant" then the frictional drag on  
16 the umbilical is greatly reduced as it moves through the  
17 wellbore. There are other details to consider such as the  
18 starting friction, any sticky substances in the well, drag  
19 due to viscous forces, etc. However, Equation 1 forms the  
20 basis for providing high electrical power through umbilicals  
21 at great distances such as 20 miles from a drilling site. As  
22 stated before in relation to this preferred embodiment, with  
23 a net force on 1,000 feet of the umbilical being only plus  
24 5.9 lbs (an upward force), assuming a coefficient of friction  
25 of 0.2, the total frictional "pull-back" on 20 miles of this  
26 umbilical is only 124 lbs.

27  
28 The preferred embodiment also calls for other reasonable  
29 design requirements on the umbilical. The umbilical needs  
30 significant axial strength (to pull the drilling machine from  
31 the well in the event of equipment failure downhole as  
32 explained later) that would require a 160,000 lbs design  
33 load. The umbilical must provide an internal pressure  
34 capacity (shut-in pressure capacity of the well) of about

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1 10,000 psi. The collapse resistance of the umbilical must  
2 exceed a 6,000 psi differential pressure. The umbilical must  
3 have the ability to work in at least 120 degrees C, and  
4 preferably, 150 degrees C. Composites are now routinely used  
5 at 120 degrees C, and experiments are now being conducted on  
6 composites at 150 degrees C. Hollow high-strength glass may  
7 replace carbon fiber composites for a cost savings, but there  
8 will be a weight penalty, thereby increasing frictional drag.

9  
10 The umbilical may occasionally be damaged during its use  
11 and require field repairs. Repairs will be accomplished by  
12 cutting out the damaged part and using field installable end  
13 connections to rejoin the intact umbilical sections. The end  
14 connections will also join various sections of umbilical that  
15 may be stored separately at the surface. These couplings are  
16 expected to slightly reduce the ID and increase the  
17 umbilical OD.

18  
19 The particular asymmetric design shown in Figure 1 was  
20 selected as a preferred embodiment in part because it  
21 illustrates the various considerations necessary to design  
22 and build such a high power umbilical that is neutrally  
23 buoyant in well fluids. Other more symmetric designs for  
24 such an umbilical are shown in another preferred embodiment  
25 shown in Figure 20 below. The references cited above in the  
26 section entitled "Description of the Related Art" provide the  
27 generally known methods used in the industry to construct  
28 composite umbilicals.

29  
30 **Figure 2** shows the uphole and downhole power management  
31 system for the composite umbilical shown in Figure 1. Wires  
32 A, B, and fiber optic cable 14, which were identified in  
33 Figure 1, are shown in Figure 2. In Figure 2, the surface of  
34 the earth is shown figurative as element 16. Any function

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1 shown above element 16 is identified as an "uphole function",  
2 and any function shown below element 16 is identified as a  
3 "downhole function".  
4

5 In Figure 2, only wires A and B of a first three phase  
6 delta circuit are shown. Three phase delta is an AC circuit  
7 having three wires (for example A, B, and C), each wire of  
8 which carries a an AC current, and there exists a voltage  
9 difference between each wire. There exists phase  
10 relationships between the current vs. time in each wire.  
11 There exits phase relationships between the voltage vs. time  
12 in each wire. However, in Figure 2, wire C is not shown for  
13 simplicity. Electrical generator 18 provides three phase  
14 delta power through cable 19 to variable voltage and  
15 frequency converter 20. The variable voltage and frequency  
16 converter possesses electronics that provides measurement of  
17 the voltages, currents and phases of the three phase delta  
18 circuit (although that electronics is not shown in Figure 2  
19 for the purposes of simplicity). Electrical power is  
20 delivered by wires A and B to the downhole electrical  
21 load 22. In one preferred embodiment, the electrical load is  
22 a downhole electric motor. The voltage, current, the  
23 relevant phases, and other parameters of the electrical load  
24 are measured with sensing unit 24. Sensing unit 24 is marked  
25 with the legend "V" indicating that at least the voltage V is  
26 measured between wires A and B at electrical load 22.  
27 Sensing unit 24 is attached to the electrical input terminals  
28 of the downhole electrical load. If this is a downhole  
29 electrical motor, the sensing unit 24 is attached to the  
30 electrical input terminals of the electric motor.  
31

32 Sensing unit 24 also possesses suitable electronics that  
33 sends the measured downhole information to the surface  
34 through optical fiber 14. The downhole information is sent

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1 by optical fiber 14 that provides the measured information to  
2 computer system 26. The measured downhole information is  
3 digitized with related instrumentation (not shown for the  
4 purposes of simplicity in Figure 2), and the downhole  
5 information is forwarded uphole by light pulses sent through  
6 the optical fiber 14.

7  
8 In Figure 2, the computer system 26 also possesses  
9 related electronics to implement the following. The computer  
10 system and related electronics provides commands to the  
11 variable voltage and frequency converter 20 by electronic  
12 feedback loop 28 to provide the necessary voltage, current,  
13 phases, and frequency as required by the downhole load 22.  
14 Consequently, Figure 2 shows a closed-loop, dynamic feedback  
15 system, where downhole load parameters are measured, the  
16 information is sent uphole, and the uphole system is  
17 automatically adjusted to provide what is required to  
18 properly operate the electrical load. The point is that the  
19 feedback loop 28 from computer 20 is used to produce the  
20 required frequency, voltage, current and phases required by  
21 the downhole load 22. This is an example of the feedback  
22 control of the downhole load 22, which may be a downhole  
23 electric motor in several preferred embodiments.

24  
25 In an alternative embodiment of feedback control, the  
26 feedback loop from computer 26 in Figure 2 is used to control  
27 the RPM of a motor generator whose 0-peak output voltage may  
28 be easily varied, which provides conveniently controlled  
29 frequency and voltage outputs, although that minor variation  
30 of the preferred embodiment is not shown in a separate figure  
31 for the purposes of brevity. In this case, the feedback loop  
32 from computer 26 is first used to control the RPM of the  
33 motor, and is also used for the second purpose to control the  
34 output voltage, frequency, and phase from the generator

1 attached to the motor which makes the motor generator  
2 assembly.

3  
4 Additional measured downhole load parameters are also  
5 sent uphole through the optical fiber. For example, in one  
6 preferred embodiment, element 22 in Figure 2 is an electrical  
7 motor, and as an example, the measured RPM, the current drawn  
8 by the motor through its input terminals, the voltage across  
9 its input terminals, and the phases of the voltages and  
10 current vs. time, the temperature, torque, etc. of that  
11 electrical motor can be sent uphole through the optical  
12 fiber 14. In other preferred embodiments, the electrical  
13 load 22 is a submersible electric drilling machine, and in  
14 another embodiment, the electrical load is a remotely  
15 operated vehicle.

16  
17 The system shown in Figure 2 controls a first three  
18 phase delta circuit that energizes wires A, B, and C in  
19 Figure 1. A second similar system to that shown in  
20 Figure 2 controls the power derived to wires D, E and F from  
21 a second three phase delta circuit. For simplicity, the  
22 second three phase delta circuit is not shown in  
23 Figure 2. Such a system is capable of delivering 320  
24 horsepower through an umbilical disposed in a wellbore shown  
25 in Figure 1 that has a length of up to 20 miles. This is  
26 important, because most of the available motors for downhole  
27 use are AC motors, and are not DC motors.

28  
29 The AC power management system shown in Figure 2 has at  
30 least several advantages. First, DC voltages are not used  
31 which would generally require a "chopper" to convert DC to AC  
32 to operate most currently available downhole electric motors.  
33 Such high power choppers are complex, often large, and  
34 generate considerable heat. Second, no downhole transformer

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1 is necessary because of the active closed-loop feedback  
2 system shown in Figure 2.

3  
4 However, the basic feedback control of downhole  
5 parameters as such as voltage and current are also useful  
6 for a DC power management system for DC electric motors that  
7 can be used in a subterranean electric drilling machine.  
8 Accordingly, another preferred embodiment of the invention is  
9 controlling DC voltages with an analogous system as outlined  
10 in Figure 2.

11  
12 **Figure 3** shows how three phase power of 160 horsepower  
13 (119 kilowatts) can be delivered through the electrical  
14 conductors in Figures 1 and 2 to distances of 20 miles.  
15 This means that this power can be delivered from 0 miles to  
16 20 miles away from a drill site for example. Two "legs" of  
17 the three phase delta circuit are shown in Figure 3 as wires  
18 A and B (wire C of the three phase delta circuit is not shown  
19 for simplicity). The resistances of a length of 20 miles of  
20 the wire is simulated with resistors having the magnitude of  
21 resistance in ohms of "R1". The legend "R1" appears in  
22 Figure 3. These two resistors are also respectively labeled  
23 as elements 30 and 32. In a preferred embodiment, the load  
24 at the end of the umbilical is simulated with a downhole  
25 electric motor 34 requiring 2,500 volts 0-peak at 45 amps  
26 0-peak between any two wires of the three phase wiring system  
27 operating at 60 Hz. As a practical case, this "downhole  
28 motor" could in principle be comprised of two each REDA,  
29 4 Pole Motors, each requiring 1250 volts 0-peak, at 45 amps  
30 0-peak, having a nominal RPM of about 1700 RPM. The current  
31 flowing through wires A and B is represented by the legend  
32  $I(t)$  in Figure 3. This required motor voltage is represented  
33 by the legend  $V_M(t)$ . The closed-loop, dynamic feedback  
34 system described in Figure 2 automatically and continuously

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1 adjusts the voltage provided downhole to the motor that is  
2 measured with sensing unit 24 in Figure 2. In this preferred  
3 embodiment, typically, the variable voltage and frequency  
4 converter 20 in Figure 2 provides 6,182 volts 0-peak and  
5 provides 45 amps 0-peak between any two legs of the three  
6 phase circuit. The supplied voltage is represented by  
7 element 36 in Figure 3. The voltage supplied by the voltage  
8 and frequency converter 20 is represented by the legend  $V_S(t)$   
9 in Figure 3. The point of this is that using the above  
10 described feedback system and reasonable gauge wiring, it is  
11 possible to actually deliver 160 horsepower (119 kilowatts)  
12 at a distance of 20 miles.

13  
14 Figure 3 shows a first independent circuit that provides  
15 2,500 volts 0-peak to a load, a motor in this preferred  
16 embodiment, at distances of up to 20 miles between wires A,  
17 B, and C respectively, and the motor may draw up to 45 amps  
18 0-peak between any pairs of wires, A-B, B-C, or C-A. A  
19 second independent circuit, that is not shown for simplicity,  
20 also provides 2,500 volts 0-peak to another motor at  
21 distances to 20 miles between wires D, E, and F respectively,  
22 and that motor may also draw up to 45 amps 0-peak from any  
23 wire D,E, and F. Such voltages and currents are necessary  
24 for two series operated REDA 4 Pole Motors, each rated for 80  
25 Horsepower (as shown in a later figure, Figure 8). REDA is a  
26 manufacturer called "Reda Div. Camco International, Inc."  
27 that may be reached at 4th & Dewey, Bartlesville, Oklahoma  
28 74005, having the telephone number of (918) 661-2000,  
29 that has a website that may be reached through  
30 [www.schlumberger.com](http://www.schlumberger.com).

31  
32 In summary, the umbilical 2 in Figure 1 must carry high  
33 power and high speed communications (320 hp - two circuits of  
34 160 hp each - and fiber optic communications). An A.C.

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1 voltage, transformerless, downhole electrical power  
2 arrangement is used. The input power and voltage are managed  
3 topside to maintain constant downhole load voltage. In one  
4 preferred embodiment, one of the two circuits is dedicated to  
5 the downhole mud pump (or Smart Shuttle™) service, while the  
6 second circuit operates other Downhole Rig™ functions such as  
7 the rotation and weight loading of a drilling bit, which will  
8 be described in later figures. In various preferred  
9 embodiments, the various downhole motors feature soft start  
10 controls allowing the topside power supply to reliably track  
11 power demand.  
12

13 In the above preferred embodiment, a three phase delta  
14 power circuit is used. In principle, any electrical power  
15 system may be used including 208 Y and related power systems,  
16 and ordinary single phase power systems.  
17

18 **Figure 4** shows an umbilical carousel in the process of  
19 being constructed. This equipment is similar to flexible  
20 pipe handling equipment now used in the industry. A first  
21 carousel flange 38 possesses interior spokes 40 that forms  
22 the inside diameter of the umbilical carousel. Wound on  
23 those interior spokes is the umbilical 42. A second carousel  
24 flange (not shown) encloses the wound up umbilical, although  
25 it not shown in the interest of brevity. In one preferred  
26 embodiment, the umbilical 42 is the same umbilical as shown  
27 in Figure 1 that is 6 inches OD. The umbilical may be stored  
28 and operated as a single line. However, the umbilical is  
29 preferably divided into several smaller lengths, as an  
30 example 5 miles each, and stored on smaller carousals or  
31 drums to reduce the fluid friction losses as compared to one  
32 20-mile continuous length. A level wind is provided on each  
33 carousel to correctly wrap the pipe as it is pulled from the  
34 well and returned to the carousel for storage.

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1           Each carousel holding 5 miles of the 6 inch OD umbilical  
2           is approximately 8 ft tall with an outside diameter of 22 ft.  
3           The mud filled umbilical weighs approximately 234 tons.  
4           Unless this equipment is installed on offshore vessels, it is  
5           not easily moved. For this reason, drilling centers where  
6           the rig is assembled are expected to use the equipment over  
7           its useful life. Such carousals may be supplied by Coflexip  
8           Stena Offshore, Inc. located at 7660 Woodway, Suite 390,  
9           Houston, Texas 77063, having the telephone number  
10          (713) 789-8540, which has its website at [www.coflexip.com](http://www.coflexip.com).  
11          Such carousals may also be supplied by Oceaneering  
12          International, Inc. located at 11911 FM 529, Houston,  
13          Texas 77401, having telephone number (713) 329-4500, which  
14          has its website at [www.oceaneering.com](http://www.oceaneering.com).

15  
16          Much surface equipment is needed in support of handling  
17          the umbilical. This surface equipment is briefly described  
18          in the following. Much of this equipment may be supplied by  
19          a firm located in Holland called Huisman-Itrec, that may be  
20          located at Admiraal Trompstraat 2 - 3115 HH Schiedam, P.O.  
21          Box 150 - 3100 AD Schiedam, The Netherlands, Harbour No. 561,  
22          having the telephone number of 31(0) 10 245 22 22, that has  
23          its website at [www.Huisman-Itrec.com](http://www.Huisman-Itrec.com).

24  
25          Stripper heads and surface blow-out preventers (BOP's)  
26          provide an OD pressure seal to the umbilical, although no  
27          figures are provided to show this feature for simplicity.  
28          This equipment has a similar function to a coiled tubing  
29          stripper head, except it handles the larger umbilical OD  
30          sizes. In practice, the actual sealing element is expected  
31          to be dual 13 5/8" annular stripping BOPs with grease  
32          injection to lubricate the sealing elements as the umbilical  
33          moves through the sealing elements. This approach of dual  
34          stripping units allows the umbilical mechanical couplings to

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1 be transitioned into the well. The surface BOPs provide for  
2 surface well control in the event of a well kick. These  
3 (shear, pipe & blind ram) BOPs will be located between the  
4 wellhead and the stripping annular units.  
5

6 An injector unit is required on the surface, although no  
7 figure is shown for simplicity. A 100-ton linear traction  
8 unit is preferred for this application. The injection unit  
9 provides drilling umbilical pushing and pulling loads at  
10 speeds to 10 feet per second. The maximum loads will be at  
11 low speeds. Speed will be limited by mudflows within the  
12 wellbore. This injector unit has a function similar to a  
13 coiled tubing injector but practically is closer in size and  
14 performance to a pipeline tensioner used to lay flexible  
15 pipe. Similar units are used for the handling and  
16 installation of flexible pipe by such firms as Coflexip Stena  
17 Offshore, Inc.; Wellstream, Inc.; and NKT Flexibles I/S. The  
18 address of Coflexip Stena Offshore, Inc. has been provided  
19 above. Wellstream, Inc. is a subsidiary of Halliburton  
20 Energy Services, and may be reached at 10200 Bellaire  
21 Boulevard, Houston, Texas 77072-5299, having the telephone  
22 number of (281) 575-4033. NKT Flexibles I/S is a firm  
23 located in Denmark having the address of Priorparken 510,  
24 DK-2605 Broendby, Denmark, having the telephone  
25 of 45 43 48 30 00, that has its website at  
26 [www.nktflexibles.com](http://www.nktflexibles.com).  
27

28 A surface mud system is required for the umbilical,  
29 although no figures showing this feature are provided for the  
30 sake of brevity. A large volume of working mud will be  
31 needed to manage the umbilical volume while tripping in the  
32 hole. For 20-mile offset operations, an active mud tank  
33 volume of 3,500 barrels may be required. This is similar to  
34 some large offshore drilling rigs in capacity. A minimum of

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1 two 750 hp surface mud pumps will be required for the  
2 preferred embodiment. The other details concerning the mud  
3 system will be presented in relation to a forthcoming figure  
4 (Figure 14).

5  
6 A surface rig is needed to support umbilical and casing  
7 operations, although no figure is presented showing this  
8 detail in the interests of brevity. The surface rig handles  
9 and makes-up the casing as it is run into the hole. In many  
10 respects, it is similar to conventional coiled tubing  
11 drilling rigs, except it is much larger in size. During  
12 drilling operations, the best method for joining expandable  
13 casing is continuing to develop. Enventure Global Technology  
14 is developing an expandable threaded joint. Enventure also  
15 has commercially available various sizes of expandable pipes  
16 and can supply various means of joining lengths of the  
17 expandable pipe. Enventure Global Technology may be reached  
18 at 16200-A Park Row, Houston, Texas 77084, having the  
19 telephone number of (281) 492-5000, that has its website at  
20 [www.EnventureGT.com](http://www.EnventureGT.com). Other alternatives of joining  
21 expandable is to weld long casing strings (similar to J-  
22 laying pipelines). The arrangement of surface rig equipment  
23 is compatible with both alternatives.

24  
25 Figure 5 shows a computerized uphole management system  
26 for the umbilical. It is a portion of a preferred embodiment  
27 of an automated system to drill and complete  
28 oil and gas wells. It is also a portion of a preferred  
29 embodiment of a closed-loop system to drill and complete oil  
30 and gas wells. Figure 5 shows the computer control of the  
31 umbilical carousel in a preferred embodiment of the  
32 invention.

33  
34  
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1           In Figure 5, computer system 26 (previously described in  
2 Figure 2) has typical components in the industry including  
3 one or more processors, one or more non-volatile memories,  
4 one or more volatile memories, many software programs that  
5 can run concurrently or alternatively as the situation  
6 requires, etc., and all other features as necessary to  
7 provide computer control of all of the uphole functions. In  
8 this preferred embodiment, this same computer system 26 also  
9 has the capability to acquire data from, send commands to,  
10 and otherwise properly operate and control all downhole  
11 functions. Therefore LWD and MWD data is acquired by this  
12 same computer system when appropriate. As a consequence, in  
13 one preferred embodiment, the computer system 26 has all  
14 necessary components to interact with a subterranean electric  
15 drilling machine. In a "closed-loop" operation of the  
16 system, information obtained downhole from the downhole  
17 system is sent to the computer system that is executing a  
18 series of programmed steps, whereby those steps may be  
19 changed or altered depending upon the information received  
20 from the downhole sensor located within the downhole system.

21  
22           In Figure 5, the computer system 26 has a cable 44 that  
23 connects it to display console 46 that has one or more  
24 display screens. The display console 46 displays data,  
25 program steps, and any information required to operate the  
26 entire uphole and downhole system. The display console is  
27 also connected via cable 48 to alarm and communications  
28 system 50 that provides proper notification to crews that  
29 servicing is required. Data entry and programming console 52  
30 provides means to enter any required digital or manual data,  
31 commands, or software as needed by the computer system, and  
32 it is connected to the computer system via cable 54.

33  
34  
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1           In Figure 5, computer system 26 provides commands  
2 over cable 56 to the electronics interfacing system 58  
3 that has many functions. One function of the electronics  
4 interfacing system is to provide information to and from any  
5 downhole load through cabling 60 that is connected to the  
6 slip-ring 62, as is typically used in the industry.  
7 Another function of the electronics interfacing system is to  
8 provide power to any downhole load through cabling 60 that is  
9 connected to the slip-ring 62. The slip-ring 62 is suitably  
10 mounted on the side of the assembled umbilical carousel 64 in  
11 Figure 5. Information provided to slip-ring 62 then proceeds  
12 to wires A, B, C, D, E, F, and G within the umbilical wound  
13 up on the umbilical carousel. The umbilical 66 proceeds to  
14 an sheave and tensioner device 68 and then the umbilical  
15 proceeds downward at location 70 towards the injection  
16 unit and on to the stripper heads and surface blow-out  
17 preventers (BOP's). The sheave an tensioner device 68 may  
18 place appropriate tension on the umbilical as required.

19  
20           In Figure 5, electronics interfacing system 58 also  
21 provides power and electronic control of the hydraulic  
22 system 72 that controls the umbilical carousel through the  
23 connector at location 74. Cabling 76 provides the electrical  
24 connection between the electronics interfacing system 58 and  
25 the hydraulic system 72 that controls the umbilical carousel.  
26 In addition, electronics interfacing system 58 has output  
27 cable 78 that provides commands and control to the drilling  
28 rig hardware control system 80 that controls various drilling  
29 rig functions and apparatus including the rotary drilling  
30 table motors, the mud pump motors, the pumps that control  
31 cement flow and other slurry materials as required, and all  
32 electronically controlled valves, and those functions are  
33 controlled through cable bundle 82 which has an arrow on it

34  
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1 in Figure 5 to indicate that this cabling goes to these  
2 enumerated items.

3  
4 In relation to Figure 5, electronics interfacing  
5 system 58 also has cable output 84 to ancillary surface  
6 transducer and communications control system 86 that provides  
7 any required surface transducers and/or communications  
8 devices required for communications with the downhole  
9 equipment. In a preferred embodiment, ancillary surface and  
10 communications system 86 provides acoustic transmitters and  
11 acoustic receivers as may be required to communicate to and  
12 from certain downhole equipment. The ancillary surface and  
13 communications system 86 is connected to the required  
14 transducers, etc. by cabling 88 that has an arrow in Figure 5  
15 designating that this cabling proceeds to those enumerated  
16 transducers and other devices as may be required. Electrical  
17 generator 18 provides three phase delta power to variable  
18 voltage and frequency converter 20 by cable 90. The output  
19 from the voltage and frequency converter 20 is provided by  
20 cable 92 to the electronics interfacing system 58. Power to  
21 wires A, B, C, D, E, F, and G, and signals to the fiber optic  
22 cable 14 (not shown in Figure 5, but which are defined in  
23 Figure 1) are provided from the electronics interfacing  
24 system 58 through cabling 60 that is connected to the slip-  
25 ring 62. The cabling 60 and the slip-ring provide  
26 the suitable electrical and fiber optic connections.  
27 Cabling 60 possesses connection to wires A, B, C, D, E, F,  
28 and G, and to the fiber optic cable 14. In certain preferred  
29 embodiments, there are two separated generators and voltage  
30 and frequency converters to independently control to first  
31 three phase delta system having wires A, B, and C, and the  
32 second three phase delta system having wires D, E, and F.

33  
34  
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1           With respect to Figure 5, and to the closed-loop system  
2 to drill and complete oil and gas wells, standard electronic  
3 feedback control systems and designs are used to implement  
4 the entire system as described above, including those  
5 described in the book entitled "Theory and Problems of  
6 Feedback and Control Systems", "Second Edition",  
7 "Continuous (Analog) and Discrete (Digital)", by J.J. DiStefano  
8 III, A.R. Stubberud, and I.J. Williams, Schaum's Outline  
9 Series, McGraw-Hill, Inc., New York, New York, 1990, 512  
10 pages, an entire copy of which is incorporated herein by  
11 reference. Therefore, in Figure 5, the computer system 58  
12 has the ability to communicate with, and to control, all of  
13 the above enumerated devices and functions that have been  
14 described to this point.

15  
16           To emphasize one major point in Figure 5, computer  
17 system 26 has the ability to receive information from one  
18 or more downhole sensors for the closed-loop system to drill  
19 and complete oil and gas wells. This computer system  
20 executes a sequence of programmed steps, but those steps may  
21 depend upon information obtained from at least one sensor  
22 located within the downhole system. This computer system  
23 provides the automatic control of the umbilical and any  
24 uphole and downhole functions related to the deployment of  
25 that umbilical.

26  
27           Figure 6 generally shows the subterranean electric  
28 drilling machine 94 that is disposed within a previously  
29 installed borehole casing 96 that is surrounded by existing  
30 downhole cement 98. The previously installed casing ends at  
31 location 100. The inside diameter of the previously  
32 installed casing is defined as "ID Casing", but this legend  
33 is not shown on Figure 6 for simplicity. The outside  
34 diameter of the previously installed casing is defined as

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1 "OD Casing", but this legend is not shown on Figure 6 for  
2 simplicity. The wall thickness of the previously installed  
3 casing is defined as "WT Casing", but this legend is not  
4 shown in Figure 6 for simplicity. The previously installed  
5 casing is located within a geological formation 102.

6  
7 As shown in Figure 6, the subterranean electric drilling  
8 machine is in the process of drilling a new borehole 104 into  
9 the geological formation. Pilot bit 106 is shown drilling  
10 the pilot hole 108. The OD of the pilot bit is defined as  
11 "OD Pilot Bit", but that legend is not shown in Figure 6 for  
12 brevity. The ID of the pilot hole is defined as "ID Pilot  
13 Hole", but that legend is not shown in Figure 6 for brevity.  
14 Undercutters 110 and 112 expand the new borehole to full  
15 diameter. The OD of the undercutters 110 and 112 when in the  
16 fully extended position is defined as "OD Undercutters", but  
17 that legend is not shown in Figure 6 for the purpose of  
18 brevity. The overall ID of the new borehole so drilled is  
19 defined to be "ID of New Hole", but that legend is not shown  
20 in Figure 6 for the purposes of brevity. The pilot bit 106  
21 and the undercutters 110 and 112 together form the entire  
22 "drill bit" of this assembly. This drill bit is an example  
23 of an "expandable drill bit", also called a "retrievable  
24 drill bit", that is also called a "retractable drill bit".  
25 The following references describe such drill bits: U.S.  
26 Patents: U.S. Patent No. 3,552,508, C.C. Brown, entitled  
27 "Apparatus for Rotary Drilling of Wells Using Casing as the  
28 Drill Pipe", that issued on 1/5/1971, an entire copy of which  
29 is incorporated herein by reference; U.S. Patent No.  
30 3,603,411, H.D. Link, entitled "Retractable Drill Bits", that  
31 issued on 9/7/1971, an entire copy of which is incorporated  
32 herein by reference; U.S. Patent No. 4,651,837, W.G.  
33 Mayfield, entitled "Downhole Retrievable Drill Bit", that  
34 issued on 3/24/1987, an entire copy of which is incorporated

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1        herein by reference; U.S. Patent No. 4,962,822, J.H. Pascale,  
2        entitled "Downhole Drill Bit and Bit Coupling", that issued  
3        on 10/16/1990, an entire copy of which is incorporated herein  
4        by reference; and U.S. Patent No. 5,197,553, R.E. Leturno,  
5        entitled "Drilling with Casing and Retrievable Drill Bit",  
6        that issued on 3/30/1993, an entire copy of which is  
7        incorporated herein by reference. Some experts in the  
8        industry call this type of drilling technology to be  
9        "drilling with casing". For the purposes herein, the terms  
10       "retrievable drill bit", "retrievable drill bit means",  
11       "retractable drill bit" and "retractable drill bit means" may  
12       be used interchangeably. The combination of the pilot bit  
13       and retractable drill bit may also be replaced under certain  
14       circumstances with a bicenter drill bit. The retrievable  
15       drill bits and the bicenter bits are rotary drill bits.

16  
17       When the undercutters 110 and 112 are retracted into  
18       their closed positions, then they can be pulled through the  
19       unexpaded casing, and then the entire subterranean electric  
20       drilling machine can removed from the previously installed  
21       casing because in their retracted positions, the OD of the  
22       undercutters is less than the ID of the expandable casing  
23       and the ID of the previously installed casing. However, when  
24       the undercutters are in their extended position as shown in  
25       Figure 6, the subterranean electric drilling machine is used  
26       to drill the new borehole.

27  
28       The downhole electric motor 114 of the subterranean  
29       drilling machine obtains its electrical energy from umbilical  
30       116. The downhole electric motor 114 is a rotary motor.  
31       In one preferred embodiment, the umbilical is the lower end  
32       of the particular composite umbilical that is shown in  
33       Figure 1. Various electrical wires and connectors along the  
34       length of the subterranean electric drilling machine conduct

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1 electrical power from the umbilical to the downhole electric  
2 motor (which are designated figuratively by element 118 which  
3 is not shown in Figure 6 for the purposes of brevity).  
4 Downhole electric motor 114 also possesses internal sensors  
5 indicating the voltages between various inputs to the motor,  
6 the current drawn by various inputs to the motor, the power  
7 consumed by the motor, the temperature of the motor, the RPM  
8 of the motor, the torque delivered by the motor, etc. That  
9 information is digitized, sent thorough suitable electrical  
10 circuitry and connectors along the length of subterranean  
11 drilling machine (designated figuratively by element 120  
12 which is not shown in Figure 6 for brevity), which digital  
13 information is then sent uphole through the fiber optical  
14 cable 14 within the umbilical in the form of  
15 suitable light pulses. Commands from the surface are also  
16 send downhole through the same bidirectional communications  
17 path. Such commands including changing RPM of the  
18 motor, etc.

19  
20 The downhole electric motor has an output shaft which is  
21 figuratively designated by element 122, which is not shown in  
22 Figure 6 for brevity. Electric motor output shaft 122  
23 proceeds through the swivel and seal unit 124 to turn rotary  
24 shaft 125 which in turn rotates the undercutters 110 and 112  
25 and the pilot bit 106. Rotary shaft 125 is also called the  
26 "drilling work string" or simply the "drill pipe". In this  
27 preferred embodiment, the undercutters 110 and 112, and the  
28 pilot bit 106 comprise the "drill bit". Therefore, in this  
29 preferred embodiment, electrical energy provided by umbilical  
30 116 to downhole electric motor 114 rotates the drill bit and  
31 bores the new borehole 104 into the geological formation.

32  
33 In Figure 6, expandable casing 126 generally surrounds  
34 rotary shaft 125. Expandable casing is described in various

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1 references in the above section entitled "Description of the  
2 Related Art". The initial OD of the expandable casing  
3 (before expansion) is defined to be "Initial OD of Expandable  
4 Casing", but that legend is not shown in Figure 6 for  
5 brevity. The initial ID of the expandable casing (before  
6 expansion) is defined to be "Initial ID of Expandable  
7 Casing", but that legend is not shown in Figure 6 for  
8 brevity. The initial wall thickness of the expandable casing  
9 (before expansion) is defined to be the "Initial WT of  
10 Expandable Casing", but that legend is not shown in Figure 6  
11 for brevity. The length of the expandable casing 126 is  
12 defined to be "Length of Expandable Casing", but that legend  
13 is not shown in Figure 6 for brevity. The Length of the  
14 Expandable Casing can be quite long, and in one preferred  
15 embodiment can be at least several thousand feet long. In  
16 such a situation, the length of the rotary shaft 125 would be  
17 approximately the same length.

18  
19 In Figure 6, the length of the submersible electric  
20 drilling machine is defined to be "Length of Submersible  
21 Electric Drilling Machine", but that legend is not shown in  
22 Figure 6 for brevity. The Length of the Expandable Casing  
23 can be much longer than the Length of Submersible Electric  
24 Drilling Machine. The broken lines 128 in Figure 6 indicate  
25 that the Length of the Expandable Casing can be quite long  
26 compared to the Length of the Submersible Electric Drilling  
27 Machine. The various elements in Figure 6 are not in  
28 proportion.

29  
30 In Figure 6, the expandable casing 126 is attached to  
31 the casing hanger 130. The casing hanger is shown in Figure  
32 7, and will be described in detail below. A portion of the  
33 casing hanger is surrounded by casing hanger seal 132. The  
34 casing hanger setting tool 134 is located within the casing

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1 hanger 130. When the new borehole 104 has been completed,  
2 the casing hanger setting tool 134 is used to expand the  
3 casing hanger so that it can make positive hydraulic and  
4 mechanical contact to the interior of the previously  
5 installed downhole casing that is adjacent to the casing  
6 hanger seal. Figure 10 below shows the casing hanger after  
7 it has been expanded with the casing hanger setting tool, but  
8 that will be described in detail in relation to that Figure  
9 10. Figure 12 below also shows the casing hanger after it  
10 has been expanded with the casing hanger setting tool, but  
11 that will be described in detail in relation to that  
12 Figure 12.

13  
14 Drilling operations typically require means to  
15 directionally drill, means to determine the location and  
16 direction of drilling, and means to perform measurements of  
17 geological formation properties during the drilling  
18 operations. Tool section 136 provides the rotary steering  
19 device for directional drilling and the LWD/MWD  
20 instrumentation packages. Here LWD means "Logging While  
21 Drilling" and "MWD" means "Measurement While Drilling".  
22 Typically, MWD instrumentation provides at least the location  
23 and direction of drilling. The LWD instrumentation provides  
24 typical geophysical measurements which include induction  
25 measurements, laterolog measurements, resistivity  
26 measurements, dielectric measurements, magnetic resonance  
27 imaging measurements, neutron measurements, gamma ray  
28 measurements; acoustic measurements, etc. This information  
29 may be used to determine the amount of oil and gas within a  
30 geological formation. Power for this instrumentation is  
31 obtained from the umbilical 116.

32  
33 In Figure 6, various electrical wires and connectors  
34 along the length of the subterranean electric drilling

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1 machine conduct electrical power from the umbilical to the  
2 rotary steering device and to the MWD/LWD instrumentation  
3 (which are designated figuratively by element 138 which are  
4 not shown in Figure 6 for the purposes of brevity). The  
5 sensors on the direction steering device and the MWD and LWD  
6 instrumentation provide information that is digitized, sent  
7 thorough suitable electrical circuitry and connectors along  
8 the length of subterranean drilling machine (designated  
9 figuratively by element 139 which is not shown in Figure 6  
10 for brevity), which digital information is then sent uphole  
11 through the fiber optical cable 14 within the umbilical in  
12 the form of suitable light pulses. Commands from the surface  
13 are also send downhole through the same bidirectional  
14 communications path. For example, commands to change the  
15 direction of drilling may be sent downhole through this  
16 bidirectional communications path.

17  
18 In Figure 6, first anchor and weight on bit mechanism  
19 (AWOBM) 140 and second anchor and weight on bit mechanism  
20 (AWOBM) 142 selectively anchor the subterranean electric  
21 drilling machine and provide suitable weight on bit for  
22 drilling purposes. First AWOBM possesses anchor means 144  
23 and 146. Second AWOBM possesses anchor means 148 and 150.  
24 This is an example of a tandem anchor system. In one  
25 preferred embodiment, the tandem anchor means 144, 146, 148  
26 and 150 are comprised of inflatable packer-like elements.

27  
28 In Figure 6, first shaft 152 couples second AWOBM to the  
29 downhole electric motor 114. In one preferred embodiment,  
30 the first shaft 152 is of fixed length. In another preferred  
31 embodiment, first shaft 152 is an extensible shaft. Mud flow  
32 channel 154 is shown in Figure 6 that will be more fully  
33 described later.

34  
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1           In Figure 6, second shaft 156 couples the first AWOBM to  
2           the second AWOBM. Second shaft 156 is an extensible shaft.  
3           In one preferred embodiment, first AWOBM can move itself with  
4           respect to one end of the second shaft 156, and second AWOBM  
5           can also move itself with respect to the opposite end of  
6           shaft 156. In one embodiment, simple electric motor operated  
7           threaded screws and nuts suitably coupled to second shaft 156  
8           are used to provide such motion. Those threaded screws,  
9           nuts, and electric motors are not shown in Figure 6 for the  
10          propose of simplicity. For other examples of related  
11          mechanisms, please refer to the following references:  
12          (a) Roy Marker, et al., in the paper entitled "Anaconda:  
13          Joint Development Project Leads to Digitally Controlled  
14          Composite Coiled Tubing Drilling System", SPE 60750,  
15          presented at the SPE/ICoTA Coiled Tubing Roundtable,  
16          Houston, Texas, April 5-6, 2000, and particularly in  
17          Figure 8 entitled "Tractor-driven BHA", an entire copy of  
18          which is incorporated herein by reference; and (b) U.S.  
19          Patent No. 5,794,703 that issued on August 18, 1998 that is  
20          entitled "Wellbore Tractor and Method of Moving an Item  
21          Through a Wellbore", an entire copy of which is incorporated  
22          herein by reference.

23  
24          First anchor and weight on bit mechanism (AWOBM) 140 and  
25          second anchor and weight on bit mechanism (AWOBM) 142 provide  
26          extension mechanisms with electric powered assemblies that  
27          are used to advance the casing and provide bit weight during  
28          drilling operations. These mechanisms also resist the  
29          drilling torque of the bit by anchoring the rotary motor.  
30          In a preferred embodiment, the anchor packers are inflated  
31          and deflated with motor driven progressing cavity pumps.  
32          Using dedicated PCPs simplifies controls and valves to  
33          operate the mechanism.

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1 First anchor and weight on bit mechanism (AWOBM) 140 and  
2 second anchor and weight on bit mechanism (AWOBM) 142  
3 are high strength anchor assemblies which provide axial load  
4 capacity at a relative slow axial advance rate. Should the  
5 suspended casing weight (in the vertical wellbore) during  
6 casing running procedures exceed the umbilical strength  
7 rating, then this mechanism may be used to lower the casing  
8 into the near horizontal wellbore.

9  
10 In Figure 6, various electrical wires and connectors  
11 along the length of the subterranean electric drilling  
12 machine conduct electrical power from the umbilical to the  
13 first anchor and weight on bit mechanism (AWOBM) 140 and to  
14 the second anchor and weight on bit mechanism (AWOBM) 142  
15 (which are designated figuratively by element 160 which are  
16 not shown in Figure 6 for the purposes of brevity). The  
17 first anchor and weight on bit mechanism (AWOBM) 140 and  
18 second anchor and weight on bit mechanism (AWOBM) 142 have  
19 many sensors including force sensors, torque sensors,  
20 position sensors, speed sensors, etc. Information from these  
21 sensors are sent thorough suitable electrical circuitry and  
22 connectors along the length of subterranean drilling machine  
23 (designated figuratively by element 162 which is not shown in  
24 Figure 6 for brevity), which digital information is then sent  
25 uphole through the fiber optical cable 14 within the  
26 umbilical in the form of suitable light pulses. Commands  
27 from the surface can also be sent downhole through this  
28 bidirectional communications path. For example, detailed  
29 commands can be sent to change the locations of first AWOBM  
30 140 and second AWOBM 142 or to change the effective load  
31 placed on the drilling bit by these mechanisms.

32  
33 In Figure 6, first mud cuttings and bypass port  
34 (MCBP) 164 allows mud and drill cuttings to pass by the

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1 first AWOBM 140. Second mud cutting and bypass port  
2 (MCBP) 166 allows mud and drill cutting to pass by the second  
3 AWOBM 142. These are electrically operated ports. Various  
4 electrical wires and connectors along the length of the  
5 subterranean electric drilling machine conduct electrical  
6 power from the umbilical to the first MCBP and to the second  
7 MCBP (which are designated figuratively by element 168 which  
8 are not shown in Figure 6 for the purposes of brevity). The  
9 first MCBP and to the second MCBP have many sensors providing  
10 temperature, pressure, etc. The information from these  
11 sensors are sent through suitable electrical circuitry and  
12 connectors along the length of subterranean drilling machine  
13 (designated figuratively by element 170 which is not shown in  
14 Figure 6 for brevity), which digital information is then sent  
15 uphole through the fiber optical cable 14 within the  
16 umbilical in the form of suitable light pulses. Commands  
17 from the surface can also be sent downhole through this  
18 bidirectional communications path. For example, detailed  
19 commands can be sent to close first MCBP and to the second  
20 MCBP to prevent a well blow-out.

21  
22 In Figure 6, mud carrying shaft 172 is attached to the  
23 first AWOBM by housing 174. The female side of universal mud  
24 and electrical connector 176 is attached to the male side of  
25 universal mud and electrical connector 178. Progressing  
26 cavity pump 180 is driven by a downhole pump motor assembly  
27 generally designated by element 182. A progressing cavity  
28 pump is abbreviated as a "PCP". Progressing cavity pump 180  
29 also includes an integral flexible shaft as is typical in the  
30 industry. In one preferred embodiment, the downhole pump  
31 motor assembly generally designated by element 182 is  
32 comprised of protector 184; first 80 horsepower electric  
33 motor 186 requiring 1250 volts at 45 amps that runs at the  
34 nominal RPM of 1700 RPM; second 80 horsepower electric motor

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1 188 requiring 1250 volts at 45 amps that also runs at the  
2 nominal RPM of 1700 RPM; universal motor base 190; gearbox  
3 protector 192; and gearbox 194 having a 4:1 reduction. The  
4 downhole pump motor assembly and a portion of the progressing  
5 cavity pump 180 is covered by shroud 196.

6  
7 Various electrical wires and connectors along the length  
8 of the subterranean electric drilling machine conduct  
9 electrical power from the umbilical to the downhole pump  
10 motor assembly (which are designated figuratively by element  
11 198 which are not shown in Figure 6 for the purposes of  
12 brevity). The subterranean electric drilling machine has  
13 has many sensors including voltage sensors, current sensors,  
14 torque sensors, temperature sensors, RPM sensors, etc. The  
15 information from these sensors are sent thorough suitable  
16 electrical circuitry and connectors along the length of  
17 subterranean drilling machine (designated figuratively by  
18 element 200 which is not shown in Figure 6 for brevity),  
19 which digital information is then sent uphole through the  
20 fiber optical cable 14 within the umbilical in the form of  
21 suitable light pulses. Commands from the surface can also be  
22 sent downhole through this bidirectional communications path.  
23 For example, detailed commands can be sent to change the  
24 the RPM of first electric motor 186 and second electric  
25 motor 188.

26  
27 Figure 6 also shows three-way valve 202. This three-way  
28 valve is used to change the direction of mud flow inside the  
29 subterranean electric drilling machine. The functions of the  
30 three way 202 valve will be described below.

31  
32 Figure 6 also shows umbilical mud valve 204. This mud  
33 valve is used to shut off mud flow, or otherwise prevent well  
34 blow-outs. The mud valve 204 has a total of three positions:

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1 (a) open, namely it allows mud to flow through as shown in  
2 Figure 6; (b) stop (not allow any mud to flow straight  
3 through); and (c) vent to the annulus between the umbilical  
4 116 and the ID of the previously installed casing 212 so that  
5 cement or cuttings can be cleaned from within the umbilical  
6 (which state is not shown in Figure 6 for simplicity).  
7

8 Various electrical wires and connectors along the length  
9 of the subterranean electric drilling machine conduct  
10 electrical power from the umbilical to three-way valve 202  
11 and to the umbilical mud valve 204 (which are designated  
12 figuratively by element 206 which are not shown in  
13 Figure 6 for the purposes of brevity). The three-way valve  
14 202 and the umbilical mud valve 204 possess many sensors  
15 including pressure sensors, voltage sensors, current sensors,  
16 and temperature sensors, etc. The information from these  
17 sensors are sent thorough suitable electrical circuitry and  
18 connectors along the length of subterranean drilling machine  
19 (designated figuratively by element 208 which is not shown in  
20 Figure 6 for brevity), which digital information is then sent  
21 uphole through the fiber optical cable 14 within the  
22 umbilical in the form of suitable light pulses. Commands  
23 from the surface can also be sent downhole through this  
24 bidirectional communications path. For example, detailed  
25 commands can be sent to change set the three-way valve 202  
26 into any position, or to close, or open, umbilical valve 204.  
27

28 In addition, Smart Shuttle™ seal 210 is shown in  
29 Figure 6. Smart Shuttle seal 210 is attached to a portion of  
30 shroud 180. For the purposes of succinct reference within  
31 this disclosure, the above entire list of Provisional Patent  
32 Applications, the U.S. Patents that have issued, the Pending  
33 U.S. Patent Applications that appear under the title of  
34 "Cross-References to Related Applications", the foreign

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1 pending Patent Applications under "Related PCT Applications",  
2 and the above U.S. Disclosure Documents under of "Related  
3 U.S. Disclosure Documents", all having William Banning Vail  
4 III as at least one of the inventors, is owned by the firm  
5 Smart Drilling and Completion, Inc. ("SDCI"), and therefore  
6 this intellectual property is defined herein to be the "SDCI  
7 Intellectual Property" or simply "SDCI IP" as an  
8 abbreviation. Smart Drilling and Completion, Inc. may be  
9 reached at 3123 - 198th Place S.E., Bothell, Washington  
10 98012, having the telephone number of (425) 486-8789, that  
11 has the website of [www.Smart-Drilling-and-Completion.com](http://www.Smart-Drilling-and-Completion.com).  
12 The Smart Shuttle is extensively described in the above  
13 defined "SDCI IP". The principal of operation of the Smart  
14 Shuttle is also described below in relation to Figure 24.  
15 The shroud 196 extends to the left in Figure 6 so that the  
16 Smart Shuttle™ seal 210 is installed on a portion of that  
17 shroud.

18  
19 In a preferred embodiment shown in Figure 6. A reverse  
20 mud circulation system has been configured with the umbilical  
21 in the wellbore. Fresh mud travels from the surface down the  
22 annuli between the well casing and the umbilical designated  
23 by element 212. The right-hand side of Figure 6 is "down" in  
24 Figure 6. Fresh mud travels down from the surface as  
25 indicated by various arrows throughout the subterranean  
26 drilling machine. Clean mud then flows through the interior  
27 of the shroud 214 to the three-way valve 202. In one  
28 preferred embodiment, the three-way valve directs mud into  
29 the input of the progressing cavity pump so that the pump  
30 boosts the pressure of the mud delivered to the drill bit.  
31 This is called "Position A" of the three-way mud valve. The  
32 detailed tubing and other hardware necessary to accomplish  
33 the details of "Position A" is not shown in Figure 6 for the  
34 purpose of simplicity. In "Position A", clean mud then flows

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1 through the interior of the male side of universal mud and  
2 electrical connector 178; then through the female side of  
3 universal mud and electrical connector 176; then through mud  
4 carrying shaft 172; then through mud flow channel 158; then  
5 through the interior of second shaft 156; then through mud  
6 flow channel 154; then through the interior of first shaft  
7 152; then through the swivel and seal unit 124; then through  
8 rotary shaft 125; and then through the mud channels in pilot  
9 bit 108.

10  
11 In Figure 6, cuttings laden mud then returns to the  
12 surface through the following path. The cuttings laden mud  
13 flows up between the outside diameter of the expandable  
14 casing 126 and the inside diameter of the new borehole 104;  
15 then through the second mud cutting and bypass port (MCBP)  
16 166; then through the first mud cuttings and bypass port  
17 (MCBP) 164; then through the volume between the exterior of  
18 the shroud 196 and the ID of the previously installed  
19 borehole casing 96; then through cross-over system 216; and  
20 then into umbilical 116 and through the umbilical mud valve  
21 204 and then to the surface of the earth through the  
22 remainder of the umbilical disposed in the wellbore.

23  
24 Cuttings laden mud returns to the surface flowing  
25 through the ID of the umbilical. The purpose is to keep the  
26 wellbore clean. The subterranean electric drilling machine  
27 94 may be recovered to the surface while cuttings and mud  
28 fill the umbilical. Time to circulate the umbilical clean is  
29 not needed prior to tripping out of the hole.

30  
31 In the preferred embodiment illustrated in Figure 6, the  
32 clean mud is provided a booster pressure to improve bit  
33 hydraulics. If a bit is selected that produces fine  
34 cuttings, the PCP mud pump is compatible with pumping the

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1 cuttings filled mud. In an alternative design, the benefit  
2 for pumping the cuttings is a reduction in backpressure held  
3 on the geological formation.  
4

5 In Figure 6, there are two other positions of the three  
6 way-valve 202, "Position B", and "Position C". In  
7 "Position B" of the three-way valve, the PCP pump 180 is not  
8 used to boost the mud pressure delivered through the mud  
9 channels of the pilot bit 108. Here, clean mud flows through  
10 the interior of the shroud 214 to the three-way valve 202,  
11 and then directly into the male side of universal mud and  
12 electrical connector 178 and through the remaining portions  
13 of the subterranean electric drilling machine to the mud  
14 channels of the pilot bit 108. The detailed configuration of  
15 pipes and other related hardware to accomplish this mode of  
16 operation is not shown in Figure 6 for the purpose of  
17 brevity.  
18

19 In Figure 6, Position C of the three-way valve 202  
20 allows the entire subterranean drilling machine to move  
21 within the previously installed borehole casing 96. The  
22 fluid filled region defined between the subterranean drilling  
23 machine and the interior of the previously installed borehole  
24 casing is designated by element 218 in Figure 6. As  
25 previously stated, the fluid filled region defined between  
26 the inside of the previously installed casing and the outside  
27 diameter of the umbilical, which is the annuli between the  
28 well casing and the umbilical, is designated by element 212.  
29 In "Position C" of the three-way valve 202, fluids are pumped  
30 from the region 218 into region 212. If there is a good seal  
31 between the exterior of the umbilical and the borehole at the  
32 surface produced by the stripper heads and surface blow-out  
33 preventers (BOP's), then the existence of the Smart Shuttle™  
34 seal 210 causes the subterranean drilling machine to go down

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1 into the well. Reversing the PCP, causes the subterranean  
2 electric drilling machine to reverse direction. For a more  
3 detailed description of the operation of a Smart Shuttle,  
4 please refer to the above defined "SDCI IP", entire copies of  
5 which are incorporated herein by reference. "Position C" of  
6 the three-way valve 202 provides an important function to  
7 rapidly trip the subterranean electric drilling machine to  
8 the surface and back should any drilling component need  
9 maintenance or replacement. This capability provides  
10 operational flexibility for the system. Based upon existing  
11 designs with currently available downhole electric motors and  
12 progressing cavity pumps, practical speeds of 10 feet per  
13 second can be anticipated while pulling a load of at least  
14 4,000 lbs.

15  
16 In Figure 6, the fluid filled region between the casing  
17 hanger seal 132 and the pilot bit 106 is designated by  
18 element 220. During drilling operations, the mud pressure in  
19 region 212 is defined to be P1; the mud pressure in the  
20 interior of the shroud defined by element 214 is P2; the mud  
21 pressure at the input to the three-way valve 202 is P3; the  
22 mud pressure within the male side of universal mud and  
23 electrical connector 178 is P4; the mud pressure inside the  
24 mud channels of the pilot bit 108 is P5; the pressure within  
25 region 220 is P5; the pressure within region 218 is P6; and  
26 the pressure within the umbilical 116 is P6.

27  
28 The subterranean electric drilling machine in  
29 Figure 6 provides other benefits. Since the anchor points  
30 secure the drilling machine in the well's casing and mudflow  
31 paths must pass through valves within the machine, the entire  
32 unit serves the function of a downhole packer with safety  
33 valve and serves as a BOP located downhole, or Downhole BOP™.  
34 The BOP is comprised of first mud cuttings and bypass port

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1 (MCBP) 164, second mud cutting and bypass port (MCBP) 166,  
2 and the umbilical mud valve 204 provide the required  
3 functions of a BOP located downhole.  
4

5 It is also worthwhile to make a few more comments about  
6 the downhole electric motor 114. This electric motor rotates  
7 the drilling bit. This electric motor may possess a gearbox  
8 to match the bit's speed requirements. Monitoring the  
9 motor's power, RPM, torque, current drawn, voltage drawn  
10 etc., provides significant information about the condition of  
11 the bit and its drilling performance. As one particular  
12 example, the electric motor is chosen to be a REDA  
13 4 pole, 80 horsepower, electric motor requiring 1250 volts  
14 at 45 amps that runs at the nominal RPM of 1700 RPM that  
15 is 5.4 inches OD and 31.5 inches long. The RPM of this motor  
16 may be conveniently varied by varying the frequency of the  
17 voltage applied to it as is indicated by Figure 2 and the  
18 related description. In one preferred embodiment, the RPM of  
19 the electric motor in the subterranean electric drilling  
20 machine is varied between about 900 RPM to 2,500 RPM.  
21 In this one preferred embodiment, the particular REDA motor  
22 does not need a gearbox for this application. In another  
23 preferred embodiment, two such REDA motors are operated in  
24 series that provide a net downhole motor capable of providing  
25 160 horsepower to a rotating drill bit at the rotation speed  
26 between 900 RPM and 2,500 RPM. The RPM and other parameters  
27 of the downhole motor are controlled by computer system 26 in  
28 Figure 5. Another preferred embodiment uses the electric  
29 motor described in U.S. Disclosure Document No. 498,720 filed  
30 on August 17, 2001 that is entitled in part "Electric Motor  
31 Powered Rock Drill Bit Having Inner and Outer Counter-  
32 Rotating Cutters and Having Expandable/Retractable Outer  
33 Cutters to Drill Boreholes into Geological Formations",  
34 an entire copy of which is incorporated herein by reference.

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1           The drilling fluid transitions from a nonrotating  
2 element which is first shaft 152, into a rotating pipe that  
3 is rotary shaft 125. The swivel and seal unit 124  
4 prevents fluid leaks in this area. Unlike a swivel-packing  
5 gland, this seal operates at a relative low differential  
6 pressure. Suitable rotating seal assemblies are commercially  
7 available for these conditions. Electric power and  
8 communications from the fixed (non-rotating) components to  
9 the rotating assembly is required. An inductive connection  
10 or a slip-ring assembly will provide the power, communication  
11 and control linkage through the swivel and seal unit 124 to  
12 the fiber optic communication system and the power available  
13 through the umbilical. However, the details for either the  
14 inductive connection or slip-ring assembly are not shown in  
15 Figure 6 in the interests of simplicity.

16  
17           Figure 6 as described above drills the borehole with the  
18 long section of expandable casing 126 carried into the new  
19 hole 104 as the new hole is drilled. However, in  
20 an alternative preferred embodiment, a short section of  
21 expandable pipe 126 is used to drill the borehole, then the  
22 subterranean electric drilling machine is retrieved from the  
23 wellbore, and then that machine conveys into the well the  
24 long section of expandable casing 126 to be cemented and  
25 expanded into place within the new borehole 104.

26  
27           Figure 6 as described, uses the pilot bit 106 and the  
28 two undercutters 110 and 112 as the "drill bit" to drill the  
29 new borehole 104. However, a bicenter bit as is used in the  
30 industry could also be used as the "drill bit" in Figure 6,  
31 provided it had suitable dimensions to be withdrawn through  
32 the ID of the unexpanded state of the expandable casing 126,  
33 and through the interior of the previously installed borehole  
34 casing 96.

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1           In relation to Figure 1, wires A, B, and C comprise the  
2 first independent three phase delta circuit. Wires D, E, and  
3 F comprise the second independent three phase delta circuit.  
4 Each separate circuit is capable of providing 160 horsepower  
5 (119 kilowatts) over an umbilical length of 20 miles.

6 In relation to Figure 6, and in one preferred embodiment, the  
7 first independent three phase delta circuit provides up to  
8 160 horsepower to the downhole electric motor 114. In  
9 relation to Figure 6, and in one preferred embodiment, the  
10 second independent three phase delta circuit provides up to  
11 160 horsepower to the downhole pump motor assembly 182 in  
12 Figure 6. In one preferred embodiment, each first and second  
13 circuit are independently controlled. So, combined, the  
14 umbilical shown in Figure 1 can deliver a total of 320  
15 horsepower (238 kilowatts) at 20 miles to do work at that  
16 distance.

17  
18           **Figure 7** shows the casing hanger 130. The casing hanger  
19 was identified with element 130 in Figure 6. A portion of  
20 the casing hanger is surrounded by casing hanger seal 132.  
21 The casing hanger seal was also previously identified with  
22 element 132 in Figure 6.

23  
24           The expandable casing 126 shown in Figure 6 is attached  
25 to the casing hanger 130. In one embodiment, the casing  
26 hanger is attached to the expandable casing by a threaded  
27 joint. In this embodiment, that threaded joint appears at  
28 end of casing hanger 222, although the threads on the casing  
29 hanger are not shown in Figure 7 for simplicity. The  
30 opposite end of the casing hanger is shown as element 223.  
31 In another preferred embodiment, the casing hanger can be  
32 manufactured integral with the expandable casing. A cement  
33 flowby port 224 is used during the cementing process as  
34 further explained in relation to Figure 10. The expandable

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1 hanger contact area is generally designated as element 226  
2 in Figure 7. The length of the expandable hanger contact  
3 area is designated by the legend L1 in Figure 7.  
4

5 **Figure 8** shows more detail for the downhole pump motor  
6 assembly that is related to element 182 in Figure 6.  
7 Elements 180, 184, 186, 188, 190, 192 and 194 were previously  
8 identified in Figure 6. Those same elements are related to  
9 the elements appearing in the following.  
10

11 Figure 8 generally shows a downhole pump motor assembly  
12 identified as element 228 which is configured as a Smart  
13 Shuttle™. In one preferred embodiment, various parts from  
14 REDA are used to make a downhole pump motor assembly 182.  
15 REDA may be located as defined above. In the embodiment,  
16 element 230 is a REDA protector for a bottom drive motor that  
17 is 5.4 inches OD, and 4.5 feet long. In this embodiment,  
18 element 232 is a first REDA 4 pole, 80 horsepower, electric  
19 motor requiring 1250 volts at 45 amps that runs at the  
20 nominal RPM of 1700 RPM that is 5.4 inches OD and 31.5 inches  
21 long. Element 234 is a power cable providing electrical  
22 power to the downhole pump motor assembly 228. In this  
23 embodiment, element 236 is a second REDA 4 pole, 80  
24 horsepower, electric motor requiring 1250 volts at 45 amps  
25 that runs at the nominal RPM of 1700 RPM that is 5.4 inches  
26 OD and 31.5 inches long. Element 238 is a REDA universal  
27 motor base part number UMB-B1 for a bottom drive motor that  
28 is 5.4 inches OD and 1.7 feet long. Element 240 is REDA  
29 gearbox protector part number BSBSB having 4 mechanical seals  
30 that is 5.4 inches OD and 10.6 feet long. Element 242 is a  
31 REDA gearbox having a 4:1 gear reduction that is 6.8 inches  
32 OD and 10.9 feet long. Element 244 is a Netzsch flexible  
33 shaft that is 7.87 inches OD and 10 feet long. Netzsch  
34 Oilfield Products is located at 119 Pickering Way, Exton,

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1 Pennsylvania 19341, having the telephone number of (610)  
2 363-8010, that has the website of [www.netzchusa.com](http://www.netzchusa.com).  
3 Element 248 is a Netzsch progressing cavity pump part number  
4 NM090\*3L (EX) that is 7.87 inches OD and 11.8 feet long.  
5 Element 248 is a crossover. Element 250 is 4 inch tubing.  
6 Element 252 is a Smart Shuttle seal. Element 254 is an  
7 intake port into the Netzsch progressing cavity pump.  
8 Element 256 is the discharge outlet from the Netzsch  
9 progressing cavity pump.

10  
11 The downhole pump motor assembly identified as element  
12 228 needs a cablehead, centralizers, bypass valves, sensors,  
13 and intelligent controls to make one embodiment of a Smart  
14 Shuttle™. Such a Smart Shuttle will have a minimum pulling  
15 force of 4400 lbs, a maximum transit speed of 11 feet per  
16 second, that operates within 9 5/8 inch O.D., 53.5 lb/foot  
17 casing. It has variable speed, is reversible, and has high  
18 speed bidirectional communications with instrumentation on the  
19 surface of the earth.

20  
21 Figure 9 shows a subterranean electric drilling machine  
22 boring a new borehole from an offshore platform. Figure 9  
23 shows the subterranean electric drilling machine 94 deployed  
24 within a previously installed borehole casing 96 that is  
25 surrounded by existing downhole cement 98 that is in the  
26 process of drilling the new borehole 104 into geological  
27 formation 102, which elements were previously defined in  
28 relation to Figure 6. Also shown in Figure 9 is the  
29 expandable casing 126 that was also defined in  
30 Figure 6. The subterranean electric drilling machine was  
31 thoroughly described in Figure 6.

32  
33 In Figure 9, an offshore platform 258 has a hoisting  
34 mechanism 260 that is surrounded by ocean 262 that is

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1 attached to the bottom of the ocean 264. The ocean surface  
2 is shown by element 265. Riser 266 is attached to blow-out  
3 preventer 268. Surface casing 270 is cemented into place  
4 with cement 272. A section of previously installed casing  
5 274 extends from the lower portion of the surface casing 270  
6 to the previously installed borehole casing 96. The broken  
7 line 276 shows that the section of previously installed  
8 casing 274 can be many thousands of feet long. Previously  
9 installed casing 274 may actually be comprised of different  
10 lengths of casings having different inside diameters, outside  
11 diameters, and weights, but that detail is not shown in  
12 Figure 9 in the interest of simplicity. Other conductor  
13 pipes, surface casings, intermediate casings, liner strings,  
14 or other pipes may be present, but they are not shown for  
15 simplicity. The upper portion of the umbilical 278 proceeds  
16 to the stripper heads and surface blow-out preventers  
17 (BOP's), then proceeds to location 70 in Figure 5, and  
18 is then wound up on the umbilical carousel 64 in  
19 Figure 5. In this preferred embodiment, the computerized  
20 uphole management system for the umbilical as shown Figure 5  
21 is mounted on the offshore platform. In Figure 9, other  
22 geological formations represented by element 280 are located  
23 above geological formation 102. Other geological formations  
24 represented by element 282 are below geological  
25 formation 102.

26  
27 In Figure 9, the directions of the arrows show the mud  
28 flow. Fresh mud travels from the surface down the annuli  
29 between the well casing and the umbilical designated by  
30 element 212. Element 212 was previously defined in  
31 Figure 6. Cuttings laden mud returns to the offshore  
32 platform 258 on the interior of the umbilical 283. The  
33 arrows show the mud flow pattern in the vicinity of the  
34 subterranean electric drilling machine 94. This mud flow

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1 system is called a "reverse mud flow system". This reverse  
2 mud flow system will keep the cuttings within the umbilical,  
3 therefore preventing any debris from accumulating in the  
4 annuli between the well casing and the umbilical that might  
5 prevent the subterranean electric drilling machine from  
6 returning to the offshore platform. In other preferred  
7 embodiments, the mud flow can be opposite - namely, clean mud  
8 flows down the interior of the umbilical, and cuttings laden  
9 mud flows up the annuli between the well casing and the  
10 umbilical.

11  
12 For the purposes of this invention, the phrase  
13 "offshore platform" includes the following: (a) bottom  
14 anchored structures that include artificial islands, gravity  
15 based structures, piled truss structures (conventional  
16 platforms), and compliant towers; (b) mobile-bottom sitting  
17 structures that include submersible structures including  
18 submersible barges (in swampy and shallow water areas),  
19 mobile gravity base structures (like the concrete islands  
20 in the Arctic) and jackup platforms; (c) floating-permanently  
21 moored structures including the tension leg platforms (TLP),  
22 the SPAR and Semisubmersible, and the Floating Production,  
23 Storage, and Offloading structures (FPSO); and (d) floating-  
24 mobile structures such as shipshape-like drilling rigs,  
25 semisubmersibles that are catenary moored, and barges.

26  
27 It is helpful to review how Figures 6, 7, 8, and 9  
28 relate to the drilling process. As was shown in Figure 6,  
29 the expandable casing 126 in its un-expanded state is carried  
30 into the hole as an outer sheath over rotary shaft 125 and  
31 associated components, which may also be called a "drilling  
32 work string". At the lower end of that borehole assembly  
33 ("BHA") is anchored into the casing. In one preferred  
34 embodiment, the string of expandable casing is 3,000 ft long.

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1           Starting with the drilling machine out of the hole, the  
2     expandable casing is run in and suspended in the wellbore  
3     from the surface. The top of the casing has an expandable  
4     casing hanger installed. Figure 7 shows the expandable  
5     casing hanger. Next, the bottom hole assembly is run through  
6     the casing and secured into the bottom joint of the  
7     unexpanded suspended casing. The casing hanger setting tool  
8     134 is secured into the casing hanger 130 together with the  
9     first and second anchor and weight on bit mechanisms 140 and  
10    142, the downhole electric motor 114, and the remaining  
11    portions of the subterranean electric drilling machine 94.  
12    The entire subterranean electric drilling machine and  
13    expandable casing is then tripped to the bottom of the well.  
14    Drilling the next section of the well continues until  
15    sufficient hole for the expandable casing has been drilled.  
16    With the expandable casing in place, the casing hanger  
17    setting tool expands and locks the unexpanded length of  
18    expandable casing in the hole. The subterranean electric  
19    drilling machine 94 then releases from the casing and is  
20    recovered from the well.

21  
22           In one preferred embodiment, the casing hanger setting  
23    tool 134 is a packer-like assembly located beneath the  
24    downhole electric motor 114. The casing hanger setting tool  
25    initially expands with sufficient pressure to secure the  
26    casing to the non-rotating housing that is connected to the  
27    swivel and seal unit 124 that centralizes the casing. Once  
28    the new hole has been drilled, and the casing hanger 130 is  
29    in proper setting position, much higher pressure is pumped  
30    into the casing hanger setting tool to plastically expand the  
31    hanger and cold forge the hanger into the previously  
32    installed borehole casing 96. As an example of this process,  
33    various manufacturers connect pipeline repair tools to  
34    pipeline ends and connect wellheads to the top of casing

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1 strings with this type of "cold forge" process. The cement  
2 flowby ports of the casing hanger are left open for  
3 circulation of cement behind the casing. When the expandable  
4 casing is later expanded, these holes are sealed through  
5 contact with overlap in the previous casing string. The  
6 casing hanger seal and cement help ensure a leak tight seal.

7  
8 In one preferred embodiment of the invention, the  
9 subterranean electric drilling machine is used to accomplish  
10 the many purposes including the following: (a) drill the new  
11 borehole 104; (b) convey into the well the expandable casing  
12 126; and (c) then using the casing hanger setting tool 134,  
13 the casing hanger is expanded into the previously installed  
14 borehole casing 96. Thereafter, the subterranean electric  
15 drilling machine releases from the casing hanger, thereby  
16 leaving the casing hanger and the expandable casing 126 in  
17 its unexpanded state in the well, and the subterranean  
18 electric drilling machine is then removed from the well.

19  
20 Thereafter, another tool called a subterranean liner  
21 expansion tool is conveyed into the wellbore. In one  
22 preferred embodiment, the subterranean liner expansion tool  
23 is labeled with element 284 in **Figure 10**. Figure 10 shows  
24 the previously installed borehole casing 96, the existing  
25 downhole cement 98, the new borehole 104, a portion the  
26 casing hanger 130 after the above expansion steps have been  
27 performed in (c) above, one end 222 of the casing hanger  
28 shown in Figure 7, and the other end 223 of the casing hanger  
29 shown in that figure. Cement flowby port 224 is also shown.

30  
31 The subterranean liner expansion tool 284 is used in a  
32 two step process. First, the cement is injected behind the  
33 unexpanded expandable casing. That process is shown in  
34 Figure 10. Second, the expandable casing is expanded. That

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1 process is shown in Figure 11. Thereafter, the subterranean  
2 liner expansion tool is removed from the well, and the well  
3 is either completed, or the well is further extended using  
4 the methods and apparatus described above.

5  
6 In Figure 10, the subterranean liner expansion  
7 tool 284 is positioned within unexpanded casing 286.  
8 Counter-rotating roller casing expander tool is generally  
9 shown as numeral 288 in Figure 10. In one preferred  
10 embodiment, clockwise rotating roller assembly 290 is on the  
11 uphole side of the counter-rotating roller casing expander  
12 tool. It has individual rollers 292, 294, 296, and 298. In  
13 this embodiment, counter-clockwise rotating roller assembly  
14 300 is on the downhole side counter-rotating roller casing  
15 expander tool. It has individual rollers 302, 304, 306 and  
16 308. Electrically powered hydraulic systems within the  
17 counter-rotating roller casing expander tool are capable of  
18 loading the individual rollers against the interior of the  
19 expandable casing. In one preferred embodiment, several of  
20 the rollers, such as roller 304, are canted through the  
21 angle  $\theta$ . In one preferred embodiment, the rollers are  
22 hydraulically loaded and are canted to advance through the  
23 expandable casing as the rotating roller assemblies 290 and  
24 300 rotate in their respective directions. Electrically  
25 powered systems within the counter-rotating roller casing  
26 expander tool are then capable of rotating the appropriate  
27 elements of each rotating roller assembly. In Figure 10, the  
28 rollers are in their fully retracted position. The electric  
29 motor and related hydraulics for the counter-rotating roller  
30 casing expander tool are located within housing 310. That  
31 electric motor is labeled with legend 312, and the related  
32 hydraulics is labeled with legend 314, although those are not  
33 shown in Figure 10 for simplicity.

1           The torque resistance section 316 is a component of the  
2 counter-rotating roller casing expander. It has longitudinal  
3 rollers 318 and 320. An electric motor 322 and associated  
4 hydraulics 324 are located within torque resistance section  
5 316 to properly actuate the longitudinal rollers 318 and 320.  
6 However, elements 322 and 324 are not shown in Figure 10 for  
7 the purposes of simplicity. The purpose of the torques  
8 resistance section 316 is to prevent any unbalanced torque  
9 resulting from the operation of the subterranean liner  
10 expansion tool that might cause the remainder of the downhole  
11 tool attached to the umbilical 116 to twist, thereby possibly  
12 breaking the umbilical. Breaking the umbilical downhole  
13 would be a catastrophic failure, although the tool can be  
14 retrieved using techniques to be described below.

15  
16           Various electrical wires and connectors along the length  
17 of the subterranean liner expansion tool conduct electrical  
18 power from the umbilical 116 to the counter-rotating roller  
19 casing expander tool 288 (which are designated figuratively  
20 by element 326 which are not shown in Figure 6 for the  
21 purposes of brevity). Sensors within the counter-rotating  
22 roller casing expander tool provide measurements such as the  
23 force delivered by the rollers to the casing, the position of  
24 the rollers, etc., which measurements are suitably is  
25 digitized and sent thorough suitable electrical circuitry and  
26 connectors along the length of subterranean liner expansion  
27 tool (designated figuratively by element 328 which is not  
28 shown in Figure 10 for brevity), which digital information is  
29 then sent uphole through the fiber optical cable 14 within  
30 the umbilical 116 in the form of suitable light pulses.  
31 Commands from the surface are also send downhole through the  
32 same bidirectional communications path. For example,  
33 commands to change the contact of the rollers, or expand the  
34

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1     rollers outward to expand the casing may be sent downhole  
2     through this bidirectional communications path.

3  
4     Figure 10 further shows progressing cavity pump 180 that  
5     is driven by a downhole pump motor assembly 182 and shroud  
6     180, which were previously described in Figure 6. Inflatable  
7     cement seal 330 is inflated during cementing operations.

8  
9     In the preferred embodiment shown in Figure 10, cement  
10    from the surface proceeds through umbilical 116; through  
11    umbilical mud valve 204 (which is used for both mud and  
12    cementing purposes); to the cross-over system 216 and into  
13    region 332; through the cement flowby port 224; through  
14    region 334 between the previously installed borehole casing  
15    96 and the exterior of the unexpanded casing 286; then into  
16    region 336 between the exterior of the unexpanded casing and  
17    the ID of the new borehole that labeled with element 338.  
18    The mud valve 204 has a total of three positions:  
19    (a) open, namely it allows cement to flow through as shown in  
20    Figure 10; (b) stop (not allow any cement to flow straight  
21    through); and (c) vent to the annulus between the umbilical  
22    116 and the ID of the previously installed casing so that  
23    cement can be cleaned from within the umbilical (which state  
24    is not shown in Figure 10 for simplicity). The region  
25    between the umbilical 116 and the ID of the previously  
26    installed casing is shown a element 212 in Figure 6, although  
27    that particular element is not shown in Figure 10 for  
28    simplicity (because of the large number of labeled elements  
29    in that vicinity of Figure 10).

30  
31    In Figure 10, the position of the "front" of the cement  
32    flow is shown by element 340. Sufficient cement is  
33    introduced into region 336 so that when the unexpanded casing  
34    286 is expanded in the next step (as explained below), then

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1 the well is properly cemented in place. Various sensors  
2 within the subterranean liner expansion tool provide data  
3 that allows the computer system 26 on the offshore platform  
4 in this embodiment to determine the proper amount of cement  
5 to be sent downhole that at least partially fills region 342  
6 that is located between the exterior of the unexpanded casing  
7 286 and OD of the new borehole 338 which is not filled with  
8 cement in Figure 10. The overlapping region between the old  
9 cement and the new cement that has not set up in Figure 10 is  
10 shown as element 344. The new cement is now allowed to set  
11 up as shown in Figure 10. However, there is old cement that  
12 is hardened in Figure 10 such as the old cement behind the  
13 casing hanger 130 that is identified with numeral 345.

14  
15 The subterranean liner expansion tool 284 is comprised  
16 of a number of components including the counter-rotating  
17 roller casing expander tool 284 and the Smart Shuttle™.  
18 The subterranean liner expansion tool is transported downhole  
19 by the Smart Shuttle™ which is comprised of components  
20 including the Smart Shuttle™ seal 210, the progressing cavity  
21 pump 180, the downhole pump motor assembly 182, and the  
22 shroud 180 which have been previously described in relation  
23 to Figure 6. The Smart Shuttle also returns the subterranean  
24 liner expansion tool to the offshore platform in this  
25 preferred embodiment.

26  
27 In a preferred embodiment of the invention shown in  
28 Figure 10, the unexpanded casing 286 is 3,000 feet long, has  
29 a weight of approximately 40 lbs/foot, and has an unexpanded  
30 OD of approximately 8.0 inches OD. In a preferred embodiment  
31 shown in Figure 10, the previously installed borehole  
32 casing 96 is a 9 5/8 inch OD casing having a weight of  
33 approximately 40 lbs/foot.

34  
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1           Figure 11 shows the subterranean liner expansion tool  
2   284. Portions of the subterranean liner expansion tool are  
3   shown in Figure 11 including the counter-rotating roller  
4   casing expander tool 288, the torque resistance section 316,  
5   and the progressing cavity pump 180 that is attached to the  
6   downhole pump motor assembly 182.

7  
8           After cementing was completed in Figure 10, the  
9   subterranean liner expansion tool is pulled up vertically  
10  above the casing hanger 130. Then the rollers of the  
11  the clockwise rotating roller assembly 290 the counter-  
12  clockwise rotating roller assembly 300 are placed in their  
13  extended positions. Then counter-rotating roller casing  
14  expander tool 288 is suitably energized, and it begins to  
15  expand the expandable casing on its downward travel (to the  
16  right-hand side of Figure 11) within the well. Figure 11  
17  shows the subterranean liner expansion tool in a location in  
18  the formation that is beyond the end of the previously  
19  installed casing 100 that is defined in Figure 10.

20  
21          In Figure 11, the expandable casing in its fully  
22  expandable form is shown at location 348. In Figure 11, the  
23  expandable casing in its unexpanded form is shown at location  
24  350. Cement surrounding the expandable casing in its fully  
25  expandable form is shown as element 352 in Figure 11. Cement  
26  surrounding the expandable casing in its unexpanded form is  
27  shown as element 354 in Figure 11. The counter-rotating  
28  roller casing expander tool 288 remains suitable energized,  
29  and it eventually completes the expansion of the expandable  
30  casing at some extreme distance in the well designed by  
31  element 356 in Figure 11. Thereafter, the liner expansion  
32  tool 284 is removed from the wellbore. Thereafter, the  
33  cement is allowed to cure. After the cement is cured, the  
34  well is completed to produce oil and gas using techniques and

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1 procedures typically used in the oil and gas industry or  
2 using those methods and apparatus described in the "SDCI IP",  
3 entire copies of which are incorporated herein by reference.  
4

5 In Figure 11, the expandable casing in its fully  
6 expandable form as shown at location 348 can also be called  
7 equivalently a "liner" because of its attachment to the  
8 previously installed casing 96 in Figure 10. Hence, the name  
9 "subterranean liner expansion tool".  
10

11 Figure 12 shows the casing hanger 130, a cement flowby  
12 port 224, the previously installed borehole casing 96,  
13 and expandable casing 126 in its unexpanded form that is  
14 attached to the casing hanger at casing hanger end 222.  
15 These elements have been previously defined in Figure 6 and  
16 in Figure 7. Figure 12 shows the casing hanger after a  
17 portion of it has been expanded with the casing hanger  
18 setting tool. The state of the casing hanger 130 in Figure  
19 12 is similar to that shown in Figure 10. The inside  
20 diameter of the previously installed borehole casing 96 is  
21 shown in Figure 12 by the legend ID2. The wall thickness of  
22 the previously installed borehole casing is identified by the  
23 legend WT2. The inside diameter of the expandable casing 126  
24 in its unexpanded form is identified by the legend ID3. The  
25 wall thickness of the previously installed borehole casing is  
26 identified by the legend WT3. This is the configuration  
27 before the passage of the subterranean liner expansion tool.  
28

29 Figure 13 provides a section view of the configuration  
30 of components shown in Figure 12 after the passage by the  
31 subterranean liner expansion tool. Various elements on  
32 Figure 13 have been previously described. In addition,  
33 element 358 shows the expandable casing in its expanded state  
34 after the passage of the subterranean liner expansion tool.

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1 Various inside diameters are defined by legends ID2, ID4, and  
2 ID5. In general, ID2 will equal ID4 that will equal ID5. If  
3 this is the case, this is a true monobore well. However,  
4 there are limitations to the power of the subterranean liner  
5 expansion tool. So, if old hard cement is set up behind the  
6 overlapping portions of the previously installed casing in  
7 the location identified by element 360, the subterranean  
8 liner expansion tool may not have sufficient power to crush  
9 old hard cement and rock behind that particular location.  
10 Such a location is identified by element 345 in  
11 Figure 10. In such event, ID4 would be less than ID2 by as  
12 much as 2 times the dimension of WT2 in Figure 12. This  
13 extra thickness may persist for the length of the casing  
14 hanger L1 as shown in Figure 7. Therefore, the installation  
15 described in Figure 13 will provide either a monobore well,  
16 or a near-monobore well.

17  
18 In the following, there are different topics of interest  
19 related to the above described preferred embodiment.  
20 Subsection titles will be used for the purposes of clarity.

21  
22 **Figure 14** shows relevant parameters related to fluid  
23 flow rates through the umbilical. Umbilical fluid flow rates  
24 are sufficient to support drilling as shown in Figure 9. One  
25 preferred embodiment uses a 4.5 inch ID pipe providing 173  
26 gallons per minute (GPM) at a pressure of 1000 pounds per  
27 square inch (PSI) pressure loss over a 20 mile offset. Here,  
28 the "Pressure Loss" is 1000 PSI. Here, the "Flow Rate" is  
29 173 gallons per minute. This was calculated using a Bingham  
30 Plastic mudflow model with 12 lb/gallon mud at a velocity of  
31 3.5 feet per second (fps). This is a "Flow Velocity" of 3.5  
32 feet per second. The umbilical geometry of 4.5 inches ID and  
33 6.0 inches OD may be optimized under different situations as  
34 required. However, these particular dimensions are selected

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1 for a reverse flow mud system inside a 8.5 inch ID cased hole  
2 having a 20-mile offset. The Bingham Plastic mudflow model  
3 is described in detail in Section 8.2 entitled "Mathematical  
4 and Physical Models" of the book entitled "Petroleum Well  
5 Construction" by Michael J. Economides, Larry T. Watters, and  
6 Shari Dunn-Norman, John Wiley & Sons, New York, New York,  
7 1998, an entire copy of which is incorporated herein by  
8 reference. An entire copy of the book referenced in the  
9 previous sentence is also incorporated herein by reference.  
10 In particular, please refer to Table 8-2 on page 222 of the  
11 book for detailed algebraic equations related to the Bingham  
12 Plastic Model.

#### 13 14 Tripping into the Well

15  
16 There are various constraints on how rapidly the  
17 subterranean electric drilling machine can enter the  
18 wellbore. Since the vertically suspended casing string and  
19 the subterranean electric drilling machine weight may be  
20 greater than can be safely run with the umbilical, the  
21 first anchor and weight on bit mechanism (AWOBM) 140 and  
22 second anchor and weight on bit mechanism (AWOBM) 142  
23 as shown in Figure 6 provide an anchor mechanism that acts as  
24 a "downhole hoist" to "walk" the casing vertically downhole  
25 and eventually into any horizontal section of the well. This  
26 "downhole hoist" is also called herein an "anchor mechanism"  
27 when used for this particular purpose. The subterranean  
28 electric drilling machine and its related anchor mechanism  
29 can be fielded from within a lubricator as is standard  
30 practice in the industry to maintain well pressure control.  
31 Once the downhole weight is within the capacity of the  
32 umbilical, use of the anchor mechanism is stopped and the  
33 casing load is transferred to the umbilical. The anchor  
34 means 144 and 146 and anchor means 148 and 150 as shown in

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1 Figure 6 of the anchor mechanism are then collapsed for rapid  
2 transit to the bottom of the well. Further downhole travel  
3 of the casing and the subterranean electric drilling machine  
4 is accomplished by pumping mud into the annulus space between  
5 the well's installed casing and the umbilical. Pressure  
6 acting upon this annular piston area generates sufficient  
7 force to rapidly move the equipment downhole at about 2 fps  
8 in the 15 to 20 mile offset range. A 225,000 lb load with a  
9 0.2 coefficient of friction requires approximately 1,600 psi  
10 differential pressure across Smart Shuttle seals (see element  
11 210 in Figure 6). This pressure capability is obtained with  
12 multiple seals load-sharing the pressure. Motion cannot be  
13 accomplished without moving mud from below the drilling  
14 machine out of the well up through the umbilical ID. The  
15 pressure in the casing below the drilling machine (a sealed  
16 volume due to cementing) is approximately 3500 psi above  
17 static. The downhole mud pump may be used to assist in  
18 moving this required mudflow through the umbilical ID. For  
19 trip velocities in the range of 2 feet per second the surface  
20 mud pumps will need to provide 350 gallons per minute at 4600  
21 pounds per square inch. At shorter distances with less  
22 pressure losses, the equipment may move faster (if surface  
23 mud pump volume capacity is available).

24  
25 **Figure 15** shows various parameters related to tripping  
26 the subterranean electric drilling machine and the expandable  
27 casing into the well. A 20 mile well is on the order of  
28 100,000 feet. At this distance, and at 2 feet per second,  
29 the formation back pressure is 1000 PSI.

#### 30 31 Tripping Out of the Well

32  
33 The subterranean electric drilling machine 94 is tripped  
34 from the well with cuttings filled mud within the umbilical.

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1 Sufficient mudflow is pumped down the annulus between the  
2 umbilical and the uphole casing to fill the entire cased  
3 wellbore below the drilling machine. The maximum pressure  
4 the pump will provide this annulus is 5000 psi and at a  
5 20 mile offset, the volume is limited to approximately 440  
6 gallons per minute or a drilling machine trip speed of  
7 approximately 2.4 fps. Simultaneously, the surface linear  
8 umbilical traction unit pulls at approximately 12,500 lbs  
9 (to overcome the fluid flow drag upon the umbilical, the  
10 frictional umbilical drag and the frictional drag of the  
11 subterranean electric drilling machine and its seals).  
12

13 As the subterranean electric drilling machine moves up  
14 the wellbore and the annular fluid pressure losses become  
15 less, the maximum mud pump pressure no longer limits the trip  
16 speed. The limiting factor then becomes the mud volumes,  
17 which the mud pumps may provide. For these tripping  
18 purposes, a third surface mud pump may be used in another  
19 preferred embodiment. It will support higher speed trips and  
20 provide redundancies during other operations.  
21

22 Since all of the mud volumes pass through the downhole  
23 mud pump, an accurate metering of the mud volume and  
24 pressures is obtained throughout the trip. This keeps  
25 pressure off the open formation during trips out of the  
26 wellbore.  
27

## 28 Surface Mud System

29

30 A large volume of working mud is needed to manage the  
31 umbilical volume while tripping in the hole. For 20-mile  
32 offset operations, an active mud tank volume of 3500 barrels  
33 may be required. This is similar in capacity to those used  
34 in some large offshore drilling rigs.

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1           In one preferred embodiment, the installed casing is  
2   8.5 inches ID, and the umbilical is a 6 inch OD umbilical  
3   with a 4.5 inch ID. During drilling operations, the maximum  
4   mud flow rate is 150 gallons per minute with a pressure drop  
5   of 825 pounds per square inch, which includes frictional  
6   losses only. During tripping out of the hole at 2.4 feet per  
7   second, the maximum mud flow rate is 422 gallons per minute  
8   with a pressure drop of 4,750 pounds per square inch. During  
9   running in the hole with casing at 2 feet per second, the  
10   maximum mud flow rate is 350 gallons per minute, with a  
11   pressure drop of 3600 pounds per square inch (with cement  
12   sealed on the bottom of the well).

13  
14           Thus, for the tripping out of the well, a minimum of  
15   two 750 hp surface mud pumps would be required. One pump is  
16   adequate for routine drilling operations. When the  
17   subterranean electric drilling machine is at a distance of  
18   20 miles, approximately 14 hours are required to run into the  
19   hole, 12 hours are required to come out of the hole, and 11  
20   hours are required for cuttings to circulate from the bottom  
21   of the hole to the surface. Therefore, accurate monitoring  
22   and management of mudflow and quality into and out of the  
23   well and umbilical both at the surface and downhole at the  
24   drilling machine is important for reliable well control.

#### 25 26                           The Drilling Operation

27  
28           When the subterranean drilling rig reaches the bottom of  
29   the hole, the high-speed bit may encounter cement within the  
30   bore of the cased hole. The anchor means 144, 146, 148 and  
31   150 as shown in Figure 6 are engaged, mud circulation started  
32   and the bit is rotated. Notice that downhole sensors monitor  
33   mudflow composition parameters to minimize circulation time  
34   for conditioning the hole. Weight on bit is applied and

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1 drilling moves forward out of the previously cased hole.  
2 Traditional steering mechanisms and MWD tools are used to  
3 guide forward progress of the bit through the formation.  
4 Directly behind this BHA is the unexpanded casing.  
5

6 The mudflow rates and the cutting solids this flow rate  
7 can transport out of the hole will limit drilling progress.  
8 For example, a drilled 12 1/2 inch ID hole and a 4 1/2 inch  
9 ID umbilical having an internal mud velocity of 3 feet per  
10 second carrying 6.5% solids will have a maximum penetration  
11 rate of 90 ft/hr.  
12

13 Significant information will be monitored and  
14 communicated real time to the surface for control of the  
15 operations. Some of the information includes:

- 16 (a) Weight on bit
- 17 (b) Penetration rate
- 18 (c) Bit RPM
- 19 (d) Bit power (determined from power consumed by the downhole  
20 electric motor 114 of the subterranean drilling machine)
- 21 (e) Mud flow rate through bit (by monitoring throughput of  
22 the progressing cavity pump 180)
- 23 (f) Differential mud pressures across bit and to surface  
24 across umbilical
- 25 (g) Mud quality sensors for entrained gas, cuttings loading,  
26 etc.
- 27 (h) Mud temperatures
- 28 (i) Basic operating parameters of the various subterranean  
29 electric drilling machine functions that include voltage,  
30 power, RPM, pressure, temperature, axial load in umbilical at  
31 the pump, etc. are all monitored in real time to verify  
32 equipment status.  
33  
34

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1           This monitoring will provide for efficient control of  
2 the downhole drilling operation. If additional information  
3 is required, in one preferred embodiment additional  
4 instrumentation or tools may be included in the umbilical at  
5 the various connection points (approximately every 5 miles).  
6 In one preferred embodiment, it is preferable to have  
7 remotely operated downhole BOP's. These devices are  
8 packer-like assemblies, which when inflated, anchor to the  
9 inside of the casing. An internal valve provides a well  
10 fluid isolation point.

11  
12           This extensive monitoring capability allows drilling  
13 operations to use under-balanced fluids, if beneficial to the  
14 well program. This equipment capability also allows for  
15 direct well control and production testing through the  
16 drilling machine.

17  
18           When the well has drilled forward to the casing point,  
19 pressuring the setting tool included in the subterranean  
20 electric drilling machine sets the expandable casing hanger.  
21 The success of the hanger setting operation may be load  
22 tested with the downhole hoist (which when used in this  
23 application is also called a "weight on bit mechanism").  
24 Upon verification of a successful operation, the subterranean  
25 electric drilling machine releases from the casing and starts  
26 its trip from the well. This will leave the well ready for  
27 casing cementing and casing expansion.

28  
29           During all operations in a wellbore, the umbilical is  
30 maintained under tension between the downhole tools and the  
31 surface equipment. This permits rapid transit in the  
32 wellbore by preventing buckling. A constraint is that a  
33 minimum number of gentle bends should be included in the  
34 wellbore design. This constraint is similar to familiar

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1 drill pipe and coiled tubing operational constraints in  
2 current well operations. Selected means to provide such  
3 tension are shown in Figure 5. The tension is monitored with  
4 computer system 26 in Figure 5.

5  
6 Several contingency operations are reviewed to  
7 illustrate the capabilities of the subterranean electric  
8 drilling system.

9  
10 The subterranean electric drilling machine can control  
11 the well and can control a well "kick", or well kicks.  
12 In one preferred embodiment, the well uses a reverse  
13 circulation system. The first mud cuttings and bypass port  
14 (MCBP) 164 and the second mud cutting and bypass port 166 in  
15 of the subterranean electric drilling machine act as a packer  
16 within the well directing all returns to the umbilical. The  
17 umbilical has sufficient pressure rating to contain any kick  
18 and allow it to be circulated from the well. Instrumentation  
19 monitoring mud conditions downhole should provide early  
20 indication of developing well control problems.

21  
22 The subterranean electric drilling machine can survive n  
23 open hole collapse. The well is drilled with unexpanded  
24 casing over the drilling work string (that is element 125 in  
25 Figure 6). Should the formation collapse on the casing, the  
26 subterranean electric drilling machine is withdrawn through  
27 the unexpanded casing. The casing may subsequently be  
28 expanded and drilling operations resumed.

29  
30 The subterranean electric drilling machine can survive a  
31 downhole blackout of power. Assume the failure is in the  
32 power transmission or control system during a tripping  
33 operation. The umbilical and surface traction winch  
34 have sufficient power to pull the dead equipment from the

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1 wellbore. Surface pumps would continue to provide mud for  
2 displacement replacement. With care, mud pressure below the  
3 subterranean electric drilling machine may be used to reduce  
4 the load required to pull the machine from the well.

5  
6 If the failure occurs when the drilling machine is  
7 anchored and making hole, then a release between the downhole  
8 mud pump and the anchor means of the drilling machine is  
9 actuated. That disconnect occurs between the female side of  
10 universal mud and electrical connector 176 and the male side  
11 of universal mud and electrical connector 178 as shown in  
12 Figure 6. In one preferred embodiment, the release may be  
13 triggered with an "over-pull" or operation may be via pumping  
14 a dart or ball down the umbilical. Once the release is  
15 actuated, the drilling machine controls, and mud pump  
16 assembly may be pulled "dead" from the well. Once the fault  
17 is isolated and repaired, the recovered equipment is run back  
18 into the well where it connects with the drilling equipment  
19 left in the hole. The Smart Shuttle portion of the  
20 subterranean electric drilling makes this reconnection.  
21 Regaining control of the equipment allows either drilling  
22 operations to proceed or for the equipment to be recovered  
23 from the well.

#### 24 25 The Well Construction Process

26  
27 Drilling and casing operations in the preferred  
28 embodiment is a two-trip process. The drilling equipment  
29 defined above (the subterranean electric drilling machine)  
30 is used to drill the hole, position and anchor the casing  
31 (but not expand it) within the hole. The casing is left in  
32 position ready for cementing operations (if required) and  
33 casing expansion to its final installed dimension is  
34

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1 accomplished with the use of a second tool system (the  
2 subterranean liner expansion tool).

3  
4 In this preferred embodiment, the new expandable casing  
5 is 3,000 feet long, 54 lbs/ft, and has an unexpanded OD of  
6 8.0 inches OD. The downhole casing hanger and the casing  
7 string are then suspended from the surface rig floor. The  
8 bottom hole assembly (BHA) is then made up and run into the  
9 casing string. In one preferred embodiment, the centralizing  
10 casing hanger setting tool is used to lock the casing and  
11 drilling equipment together. Next the rotary motor and the  
12 anchor mechanism are added to the assembly together with the  
13 downhole mud pump that may be used as a Smart Shuttle.

14  
15 This described equipment is all long and heavy. It is  
16 handled as major assemblies with quick connection devices  
17 between each assembly. The estimated size and weight of  
18 various components appear below in the following.

19  
20 The bit is about 2 feet long, and weighs 500 lbs in air.  
21 The MWD tools are 40 feet long and weigh about 1,200 lbs in  
22 air. The rotary steering tool is about 30 feet long, and  
23 weighs 1,500 lbs in air. The rotary shaft (element 125 in  
24 Figure 6) also called the "drilling work string" or simply  
25 "drill pipe", is about 3,000 feet long and weighs 28,500 lbs  
26 in air. The expandable casing has a weight of 54 lbs/ft, is  
27 about 3,000 feet long, and weighs 162,000 lbs in air. The  
28 rotary section and anchor section of the subterranean  
29 electric drilling machine (that includes elements 114, 140  
30 and 142 in Figure 6) is about 120 feet long and weights  
31 2,800 lbs. The downhole mud pump section of the subterranean  
32 electric drilling machine (including elements 180, 196, and  
33 214 in Figure 6) is about 122 feet long and weighs about  
34 3,900 lbs in air. Any separate control module associated

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1 with the subterranean electric drilling machine is about 20  
2 feet long and has a weight of 4,000 lbs. So, the total  
3 length of the assembly is about 3,334 feet long that weighs  
4 about 200,800 lbs in air.

#### 5 6 Cementing and Expanding the Casing 7

8 In this preferred embodiment of the invention,  
9 subterranean liner expansion tool 284 in Figure 10  
10 installs the cement and expands the monobore casing in the  
11 well. This approach was selected to simplify the  
12 subterranean electric drilling machine and to provide  
13 operational flexibility when performing these monobore well  
14 construction operations.

15  
16 The subterranean liner expansion tool has two basic  
17 functions. The first is to cement the casing in the well  
18 (if required). In one embodiment, this is accomplished  
19 through a 2 inch cementing line in a 3 1/2 inch  
20 OD umbilical. Unlike the subterranean electric drilling  
21 machine when attached to casing, the Smart Shuttle at speeds  
22 up to 10 feet per second pulls this umbilical into the well.  
23 The Smart Shuttle operation of the liner expansion tool  
24 requires that the inflatable cement seal 330 is collapsed,  
25 and then fluids are pumped from the downhole side of the  
26 Smart Shuttle™ seal 210 to the uphole side of that seal as  
27 has been previously described. To cement the well,  
28 inflatable cement seal 330 is inflated. This cement seal is  
29 also called a straddle seal (with one side being inflatable)  
30 on the tool's outside diameter that ensures the fluid  
31 connection between the umbilical and the cement ports in the  
32 casing hanger. Once the tool is in place, cement is  
33 circulated into the annulus space behind the unexpanded  
34 casing. Adequate instrumentation monitors cement placement,

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1 volume and Smart Shuttle location and reports all of these  
2 monitored parameters to the surface.

3  
4 The second function of the subterranean liner expansion  
5 tool is to expand the casing to its final operating size.  
6 The roller mechanisms for this task have already been  
7 described in relation to Figure 10. Rollers provide power,  
8 control and reversibility. If the casing were expanded with  
9 internal pressure, it would lack any expansion control - for  
10 example, if the hole diameter were irregular, then the casing  
11 expansion would be irregular as well. Expansion dies have  
12 the problem of being a one shot, one size expansion process.  
13 Internal casing rollers have experience in buckled casing  
14 repair tools and in anchoring casing inside Unibore  
15 wellheads. Weatherford has developed a one step expansion  
16 tool for expanding casing that is featured on their website.  
17 Weatherford International, Inc. may be reached at 515 Post  
18 Oak Blvd, Suite 600, Houston, Texas 77027, having the  
19 telephone number of (713) 693-4000, that has the website  
20 of [www.weatherford.com](http://www.weatherford.com). In Figure 10, the counter-rotating  
21 roller casing expander tool 288 has contra-rotating rollers  
22 to minimize the tool's torque that has to be externally  
23 reacted while expanding the casing. The longitudinal rollers  
24 318 and 320 in Figure 10 provide for this torque reaction.  
25 As previously described, a downhole motor powered with a  
26 separate electrical circuit from the surface provides the  
27 necessary rotary power.

28  
29 In a preferred embodiment, the surface equipment is  
30 similar in arrangement to the drilling machine system.  
31 However, this equipment may be smaller as the umbilical  
32 OD may be chosen to be 3 1/2 inches OD.

33  
34  
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1           As described earlier, in one mode of operation of the  
2 subterranean electric drilling machine, it acts like a Smart  
3 Shuttle. The Smart Shuttle will be used to pump the  
4 umbilical and the subterranean liner expansion tool to the  
5 downhole worksite. The Smart Shuttle works by pumping fluid  
6 from one side of the seals to the other with an electric  
7 powered progressive cavity pump (PCP) (or any positive  
8 displacement pump). At relative low differential pressures,  
9 large axial forces ( approximately 4,000 lbs net) are  
10 generated that are sufficient to pull the tool and umbilical  
11 into the hole. Top-hole speeds are the maximum design speed  
12 of 10 fps. At extreme offsets, the speed will be slower (2.5  
13 feet per second) due to fluid drag force on the umbilical,  
14 which will be proportional to the transit speed.

15  
16           The Smart Shuttle system is equipped with sensors to  
17 detect location and to easily position the tools straddle  
18 seals across the casing hanger of the last casing string.  
19 Once in position, the inflatable seal is inflated and  
20 circulation through the hole-casing annulus is confirmed.  
21 This may be accomplished by pumping from the surface or by  
22 using the Smart Shuttle pump to circulate the area. Cement  
23 will be spotted into the annulus and the casing will be  
24 expanded prior to the cement hardening.

25  
26           Figure 10 illustrates the subterranean liner expansion  
27 tool with cement being injected from the surface through the  
28 umbilical. Approximately 69 gallons per minute will flow at  
29 100,000 ft with a pressure loss of about 9,000 pounds per  
30 square inch. Thus, the cementing pump will have to deliver  
31 at 10,000 pounds per square inch at these rates. It will  
32 require 240 minutes for the cement to be delivered at 100,000  
33 ft from the surface and then another 77 minutes to spot  
34 approximately 126 barrels of cement into the hole-casing

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1 annulus space. When operating at these large offsets,  
2 managing the setting time of the cement and the required  
3 volume of cement is important.

4  
5 Tracers may be added to the fluid pads before and  
6 following the cement as it is pumped into the umbilical.  
7 Sensors located on the subterranean electric drilling machine  
8 will verify when the cement is passing these downhole sensor  
9 locations. This will help accurately spot cement into the  
10 well. Once the cement is out of the umbilical, a bypass  
11 valve is opened and mud is circulated through the annulus to  
12 clear the umbilical.

13  
14 Some casing may not require to be cemented into the  
15 hole. It may be possible that the casing can be expanded  
16 into the wall of the hole with sufficient pressure that the  
17 residual contact stress between the rock and expanded casing  
18 are sufficient to form an axial fluid seal. This avoids the  
19 cementing step and simplifies operations. However, it places  
20 a significant load upon the casing expansion rollers.

21  
22 Once the cement is in position within the hole-casing  
23 annulus, the inflatable cement seal 330 is deflated and the  
24 Smart Shuttle pulls the expansion tool back into the  
25 previously cased wellbore. The counter-rotating roller  
26 casing expander tool is energized, and its roller engage the  
27 casing ID by expanding until contact with the casing is  
28 established. Rotation of the rollers is begun and the tool  
29 slowly moves forward. Forward motion is provided by the  
30 slight canted angle of the rollers, which screw the expander  
31 into the casing hanger and pipe. This canted angle is shown  
32 as the angle  $\theta$  in Figure 10. In one preferred embodiment,  
33 the counter-rotating roller casing expander tool has  
34 sufficient strength to expand the casing hanger and the

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1 previously set casing back into the formation to provide a  
2 smooth casing ID. This process is illustrated in Figures 12  
3 and 13. Figure 12 shows the casing hanger area prior to  
4 tool's passage and Figure 13 illustrates this same region  
5 after the tool has passed. The subterranean liner expansion  
6 tool has to have sufficient strength to expand the two casing  
7 strings back into the formation rocks.

8  
9 The subterranean liner expansion tool continues  
10 expanding the casing to the bottom of the string. The  
11 process of expanding the casing will reposition the cement  
12 that is in the annuli. It will be extruded along the  
13 reducing annuli until the cement reaches the end of the  
14 casing where excess will flow into the uncased hole below the  
15 expansion machine. Once the casing has been fully expanded,  
16 the rollers of the subterranean liner expansion tool are  
17 collapsed to their small transport size and the Smart Shuttle  
18 and surface traction winch are used to bring the tool to the  
19 surface. This leaves the hole ready for the next drilling  
20 cycle.

21  
22 Drilling and monobore casing operations continue until  
23 the well reaches the target reservoir. It is then possible  
24 to drill lateral drainholes (using a similar process) or a  
25 single large bore completion may be made.

26  
27 There are various methods to handle contingencies with  
28 the subterranean liner expansion tool. Similar to the  
29 subterranean electric drilling machine, considerable  
30 flexibility exists in the cementing and expansion tool  
31 concepts to handle most contingencies. A few of these  
32 contingencies illustrate this capability.

33  
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1           Suppose the power to the subterranean liner expansion  
2 tool is cut off during a tip into the well.. A bypass valve  
3 around the Smart Shuttle pump will open and allow the tool to  
4 be pulled from the wellbore using the surface linear winch  
5 and the strength of the umbilical. Alternatively, in some  
6 wells, it may be possible to pump mud down the cement line in  
7 the umbilical and apply pressure below the Smart Shuttle to  
8 assist in its retrieval.

9  
10           Suppose there is a loss of power with cement in the  
11 umbilical. Then, a downhole bypass valve will open  
12 connecting the umbilical bore with the cased well annulus.  
13 Mud pumps may then be used to flow the cement to the surface.

14  
15           Suppose the subterranean liner expansion tool fails  
16 without expanding the entire casing string. The tool is then  
17 recovered and the cement in the well annulus is assumed to  
18 harden. The next drilling operation will be to mill out of  
19 the wellbore and sidetrack to resume drilling to target.

20  
21           Suppose the expansion strength of the subterranean liner  
22 expansion tool is not sufficient to expand the casing hanger  
23 to a full bore ID. The subterranean liner expansion tool has  
24 the capability of operating at various diameters. It will  
25 expand the casing to gage diameter where ever possible. Some  
26 areas, (like the casing hanger area) may not achieve gage -  
27 especially if the formation is exceptionally hard/strong.  
28 The under gage diameter is not desirable, but not a  
29 significant problem as all of the tool systems should pass  
30 through this reduced diameter. Should it not be possible to  
31 achieve the minimum gage diameter, then a mill may be used to  
32 increase inside diameter as a last resort.

33  
34  
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## Casing Flotation Techniques

Casing flotation techniques may be used to dramatically reduce the well annuli pressure required to pump casing into the well or reduce the required downhole hoist capacity. Air or nitrogen may be enclosed within the casing at the surface to reduce its apparent weight in mud during running operations. Once on bottom, the near buoyant casing would be flooded and filled with mud so that operations as previously described would continue. This and other related weight saving concepts have the potential to reduce the well annuli running pressure or downhole hoist capacity by 90% as compared to the loads identified above in the section entitled "The Well Construction Process". This capability allows much longer and/or heavier strings of casing to be optionally run.

Casing flotation techniques will not have an impact upon the umbilical's design criteria. The umbilical's internal working pressure defines its required axial strength. A 10,000 psi internal pressure for well control requires an umbilical axial load strength of approximately 160,000 lbs to resist the surface pressure effects.

## Alternative Embodiments of Drilling Systems

In Figure 6, first anchor and weight on bit mechanism (AWOBM) 140 and second anchor and weight on bit mechanism (AWOBM) 142 are an example of "anchors" or "anchor means". In the following summary, the term "Anchor Means" may be capitalized.

In Figure 6, the expandable casing 126 is being "pushed" deeper into the wellbore by the anchor means. Therefore,

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1 this configuration is called a "Drill & Push" configuration.  
2 In this situation, the anchor means are on the uphole side of  
3 the subterranean electric drilling machine. On the other-  
4 hand, if the anchor means were instead on the downhole side  
5 of the subterranean electric drilling machine, then this  
6 configuration would be called a "Drill & Drag" configuration.

7  
8 In Figure 6, the anchor means are located on the inside  
9 of the previously installed borehole casing 96. In this  
10 configuration, the anchor means are located within the  
11 "Wellbore". On the other-hand, if the anchor means are  
12 instead located within the new borehole 104, then the anchor  
13 means are located in the "Open-Hole".

14  
15 In Figure 6, the downhole electric motor 114  
16 rotates the rotary shaft 125 that is also called the  
17 "drilling work string" or simply the "Drill Pipe".  
18 In Figure 6, the downhole electric motor rotates the Drill  
19 Pipe. Therefore, the "rotary means", in Figure 6 is  
20 described by the following: "Rotates Drill Pipe". In  
21 Figure 6, the expandable pipe 126 is not rotated. However,  
22 there are other configurations of the rotary means including:  
23 "Rotates Drill Pipe and Casing", and "In Open Hole Rotates  
24 Bit". In the below defined list of different preferred  
25 embodiments, the term "rotary means" is capitalized as  
26 "Rotary Means".

27  
28 In Figure 6, the expandable casing 126 is not rotated.  
29 Therefore, in this configuration, the expandable casing is  
30 "Non-Rotating". In other preferred embodiments, the  
31 expandable casing can be rotated by the rotary means. In  
32 this configuration, the expandable pipe is "Rotated".  
33  
34

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1           In Figure 6, the progressing cavity pump 180 is driven  
2 by a downhole pump motor assembly generally designated by  
3 element 182 that comprises the mud pump, or "Mud Pump" in  
4 Figure 6. In this preferred embodiment, the Mud Pump is  
5 located within the Wellbore.

6  
7           Accordingly, the preferred embodiment shown in Figure 6  
8 can be described as follows (Preferred Embodiment "A"):

9       Arrangement: Drill & Push

10      Anchor Means: In Wellbore

11      Mud Pump: In Wellbore

12      Rotary Means: Rotates Drill Pipe

13      Expandable Casing: Non-Rotating

14      Comments: Preferred Embodiment shown in Figure 6.

15  
16           Accordingly, another preferred embodiment of the  
17 invention may be succinctly described as follows  
18 (Preferred Embodiment "B"):

19      Arrangement: Drill & Push

20      Anchor Means: In Wellbore

21      Mud Pump: In Wellbore

22      Rotary Means: Rotates Drill Pipe and Expandable Casing

23      Expandable Casing: Rotating

24      Comments: This requires higher rotary torque than  
25                Preferred Embodiment "A".

26  
27           Accordingly, another preferred embodiment of the  
28 invention may be succinctly described as follows  
29 (Preferred Embodiment "C"):

30      Arrangement: Drill & Drag

31      Anchor Means: In Open Hole

32      Mud Pump: In Wellbore

33      Rotary Means: In Open Hole, Rotates Drill Bit

34      Expandable Casing: Non-Rotating, Drags Behind Anchor Means

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1       Comments: This requires stable formations for  
2                   Open Hole Anchor Means.

3  
4           Accordingly, another preferred embodiment of the  
5 invention may be succinctly described as follows (Preferred  
6 Embodiment "D"):

7   Arrangement: "Drainhole Drilling"

8   Anchor Means: In Wellbore

9   Mud Pump: In Wellbore

10   Rotary Means: Rotates Drill Pipe

11   Expandable Casing: Non-Rotating

12   Comments: Similar to Preferred Embodiment "A", except  
13               smaller diameters of expandable casing used.

14  
15           In the above, Preferred Embodiment "C" is further  
16 described in the following document: U.S. Disclosure  
17 Document No. 494374 filed on May 26, 2001 that is entitled in  
18 part "Continuous Casting Boring Machine", an entire copy of  
19 which is incorporated herein by reference.

20  
21           In the above, Preferred Embodiment "D" is further  
22 described in the following document: U.S. Disclosure  
23 Document No. 495112 filed on June 11, 2001 that is entitled  
24 in part "Liner/Drainhole Drilling Machine", an entire copy of  
25 which is incorporated herein by reference.

26  
27           The subterranean electric drilling machine has been  
28 illustrated performing hydrocarbon drilling applications.  
29 However, there are other preferred embodiments of the  
30 invention. The subterranean electric drilling machine has  
31 the capability of performing directional drilling over large  
32 distances both onshore and offshore. This includes drilling  
33 pipelines under large and deep rivers, across large  
34 topographical features like cliffs or subsea escarpments.

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1 Other applications for the subterranean electric drilling  
2 machine include near surface drilling in urban areas for  
3 installation or replacement of utilities like water lines,  
4 gas mains, sewers, storm drains, underground power lines, and  
5 communication lines, including broadband cables and fiber  
6 optic cables. The selected drill bit would be sized for the  
7 application. These preferred embodiments are not further  
8 described herein in the interests of brevity.

9  
10 **Figure 16** is similar to Figure 9, except here the well  
11 is being drilled from an onshore wellsite. Subterranean  
12 electric drilling machine 94 is disposed within a previously  
13 installed borehole casing 362 that is surrounded by existing  
14 downhole cement 364. The subterranean electric drilling  
15 machine 94 was described in relation to Figure 6. The  
16 subterranean electric drilling machine is in the process of  
17 drilling a new borehole 366 into geological formation 368.  
18 Expandable casing 370 is carried into the new borehole by the  
19 subterranean electric drilling machine. Umbilical 372  
20 connects the subterranean electric drilling machine to a  
21 land-based drill center 374 that has the hoist, the computer  
22 systems, the umbilical carousel, etc. Surface casing 376 is  
23 surrounded by cement 378. The bottom of the surface casing  
24 is connected to previously installed casing 362 by casing  
25 string 380. The ocean 382 has ocean surface 384 and ocean  
26 bottom 386. Here, the new borehole is being drilled beneath  
27 the ocean from a land-based drill center. The land 388 joins  
28 the ocean at a beach 390.

29  
30 **Figure 17** is similar to Figure 9 and Figure 16, except  
31 here the well is being drilled from a land based drill site.  
32 Subterranean electric drilling machine 94 is disposed within  
33 a previously installed borehole casing 392 that is surrounded  
34 by existing downhole cement 394. The subterranean electric

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1 drilling machine 94 was described in relation to Figure 6.  
2 The subterranean electric drilling machine is in the process  
3 of drilling a new borehole 396 into geological formation 398.  
4 Expandable casing 400 is carried into the new borehole by the  
5 subterranean electric drilling machine. Umbilical 402  
6 connects the subterranean electric drilling machine to the  
7 land based drill site generally designated by element 404.  
8 Shown figuratively are hoist 406; the umbilical carousel,  
9 computers, etc. 408; and another section of umbilical 410.  
10 Element 411 figuratively shows a lubricator. Surface casing  
11 412 is surrounded by cement 414. The bottom of the surface  
12 casing is connected to previously installed casing 392 by  
13 casing string 416. The surface of the earth is identified by  
14 element 418.

15  
16 **Figure 18** shows a subterranean electric drilling machine  
17 420 that is drilling an open borehole in the earth.  
18 Element 420 is called an open hole subterranean electric  
19 drilling machine. Electric motor 422 turns shaft 424 that  
20 rotates the rotary drill bit 426 that drills borehole 428 in  
21 geological formation 430. First anchor and weight on bit  
22 mechanism (AWOBM) 432 is connected to second anchor and  
23 weight on bit mechanism (AWOBM) 434 by extensible shaft 436,  
24 which elements comprise an anchor mechanism. Shaft 438  
25 connects the female side of universal mud and electrical  
26 connector 440 to the male side of universal mud and  
27 electrical connector 442. Progressing cavity pump 444 is  
28 driven by its pump motor 446. Inflatable seal 448 surrounds  
29 the progressing cavity pump that makes a positive seal  
30 against the borehole wall of geological formation 449. The  
31 progressing cavity pump has inlet 450 and outlet 452. The  
32 inflatable seal 448 and the progressing cavity pump form a  
33 Smart Shuttle that can be used to move the open hole  
34 subterranean electric drilling machine shown in Figure 18 in

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1 and out of the hole. Centralizer 454 is attached to the  
2 portions of the tool body having electronics 456 and  
3 bidirectional communications 458 with the surface. Mud  
4 carrying umbilical 460 is connected to the cable head 462  
5 that provides electrical power and mud to the open hole  
6 subterranean electric drilling machine. Mud from the surface  
7 through the umbilical proceeds down the interior of various  
8 elements of the drilling machine that are not shown for  
9 simplicity, and then mud laden cuttings return to the surface  
10 through the annulus 464 between the borehole wall and the  
11 outside diameter of the umbilical. The arrows in  
12 Figure 18 show the direction of mud flow. The inflatable  
13 seal 448 surrounding the progressing cavity pump is partially  
14 collapsed during actual drilling operations to allow the mud  
15 to pass. The inflatable seal 448 is inflated when quickly  
16 transporting the open hole subterranean electric drilling in  
17 and out of the well. In view of the detailed description  
18 provided in Figure 6 and elsewhere, and in view of the  
19 description herein, it is now evident how the open hole  
20 subterranean electric drilling machine functions.  
21 Accordingly, no further detail will be presented here in the  
22 interests of brevity.

23  
24 **Figure 19** shows another subterranean electric drilling  
25 machine 466 that is drilling an open borehole in the earth.  
26 Element 466 is another embodiment of an open hole  
27 subterranean electric drilling machine called a "screw drive  
28 subterranean electric drilling machine". Figure 19 is  
29 similar to Figure 18. Elements 422, 424, 426, 432, 434, 436,  
30 438, 440 and 442 have been defined in relation to  
31 Figure 18.

32  
33 The fundamental change in Figure 19 is that the form of  
34 the Smart Shuttle shown in Figure 18 has been replaced by the

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1 screw translator device 468. Element 470 has an electric  
2 motor 472 (not shown for simplicity), related electronics,  
3 and bidirectional communications electronics. When electric  
4 motor 472 rotates the screw blades 474, then friction against  
5 the mud in the hole 476 causes the screw translation device  
6 468 to translate within the hole (if the anchor means of  
7 elements 432 and 434 are in their retracted positions).  
8 Reversing the rotation of the screw blades reverses the  
9 direction of translation within the borehole. The female  
10 side of universal mud and electrical connector 478 is  
11 attached to the male side of universal mud and electrical  
12 connector 480, that is in turn connected to umbilical 482,  
13 however, elements 480 and 482 are not shown in Figure 19 for  
14 the purposes of simplicity. Centralizers 484 centralize  
15 element 470 within the wellbore 486. The arrows show the  
16 path of the mud flow during drilling operations. In view of  
17 the previous disclosure, it is evident how the screw drive  
18 subterranean electric drilling machine is used to drill the  
19 new borehole 488 in the geological formation 490.

20  
21 In another preferred embodiment in Figure 19, the  
22 screw blades 474 have a variable pitch, where the distance  
23 between successive blades is a smaller distance to the  
24 right-hand side of Figure 19 than to the left-hand side of  
25 Figure 19. In yet another preferred embodiment, the pitch  
26 between the screw blades 474 is variable and controlled by  
27 the surface computer system 26. Various embodiments of  
28 the "screw drive subterranean electric drilling machine" are  
29 further described in U.S. Disclosure Document No. 494374  
30 filed on May 26, 2001, that is entitled in part "Continuous  
31 Casting Boring Machine", an entire copy of which is  
32 incorporated herein by reference.

33  
34  
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1           Figure 20 shows a cross section of another embodiment of  
2 an umbilical used for subterranean electric drilling machines  
3 and for open hole subterranean electric drilling machines. A  
4 version of Figure 20 was originally filed in the U.S.P.T.O.  
5 on the date of October 2, 2000 as a portion of U.S.  
6 Disclosure Document 480550. Umbilical 492 contains at least  
7 one insulated electrical conductor 494. Each such conductor  
8 has electrical copper conductors 496 encapsulated by  
9 electrical insulation 498. As shown in Figure 20, there are  
10 a total of 8 such insulated electrical conductors. In one  
11 embodiment, the insulated electrical conductors may be chosen  
12 to be the same as shown in Figure 1. Also shown is high  
13 speed bidirectional data communications means 500, which may  
14 be a fiber optic cable or a coaxial cable. The insulated  
15 electrical conductors and the high speed bidirectional data  
16 communication means is encapsulated by first composite  
17 material 502. Second composite material 504 surrounds first  
18 composite material. As described above, the specific  
19 gravities of composite materials 502 and 504 may be  
20 engineered so that the umbilical 492 is substantially  
21 neutrally buoyant in wellbore fluids.  
22

23           In one preferred embodiment of the invention in  
24 Figure 20, the second composite material 502 is chosen for  
25 its good strength, durability against abrasion in the well,  
26 and perhaps for its electrical insulation properties. In one  
27 embodiment of Figure 20, the first composite material is  
28 chosen so with a particular specific gravity such that the  
29 overall umbilical is neutrally buoyant in typical well fluids  
30 (in 12 lb per gallon mud, for example, or in salt water, as  
31 another example). As previously discussed, syntactic foam  
32 materials having silica microspheres as provided by the  
33 Cumming Corporation ([www.emersoncumming.com](http://www.emersoncumming.com)) for such  
34 purposes. The details on pressure balanced silica

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1        microspheres in syntactic foam may be reviewed in  
2        Attachment 28 to the Provisional Patent Application Number  
3        60/384,964 filed on June 3, 2002 that is entitled "Umbilicals  
4        for Well Conveyance Systems and Additional Smart Shuttles and  
5        Related Drilling Systems", an entire copy of which is  
6        incorporated herein by reference.

7  
8        The interior 506 of the umbilical is used to provide  
9        drilling fluids or cement downhole as required. Therefore,  
10       different embodiments of umbilicals provide electric power  
11       downhole, bidirectional communications, and provide the  
12       ability to conduct fluids to and from the borehole, which are  
13       neutrally buoyant in the fluids present. Umbilicals handling  
14       well fluids are also useful with a number of well services  
15       including the use with straddle packers, injection tools, oil  
16       gas separators, flow line cleaning tools, valves, etc. In  
17       another preferred embodiment, the interior 506 may be filled  
18       with composite materials to provide extra strength for  
19       certain applications that is also substantially neutrally  
20       buoyant.

21  
22       **Figure 21** shows yet another neutrally buoyant composite  
23       umbilical in 12 lb per gallon mud. Outer spoolable composite  
24       tubing 508 has an OD shown by legend OD6, and has an ID shown  
25       by legend ID6. In a preferred embodiment, OD6 is equal to  
26       1.75 inches O.D., and ID6 is equal to 1.25 inches I.D. In  
27       one preferred embodiment, the composite tubing is chosen to  
28       have a specific gravity of 1.50.

29  
30       Three each 0.355 inch O.D. insulated No. 4 AWG Wires  
31       510, 512 and 514 are disposed within the I.D. of the  
32       spoolable composite tubing. Optical fiber 516 is also  
33       disposed within the spoolable composite tubing. The  
34       remaining available volume within the spoolable composite 518

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1 is then filled with pressure balanced silica microspheres in  
2 syntactic foam that has a specific gravity of 0.60. A  
3 calculation shows that this umbilical in 12 lbs/gallon mud  
4 weighs -50 lbs for every 1,000 feet. Assuming a coefficient  
5 of friction of 0.2, at 20 miles the umbilical could pull back  
6 with a frictional force of 1,056 lbs. So, this umbilical is  
7 substantially neutrally buoyant (or simply "neutrally  
8 buoyant" as defined below).

9  
10 In Figure 21, the insulated wire is rated at 14,000  
11 volts. This particular wire is Part Number FEP4FLEXSC  
12 available through Allied Wire & Cable located in Bridgeport,  
13 Pennsylvania. This wire was previously described in relation  
14 to Figure 1. As is evident from the discussion involving  
15 Figure 1, the three power conductors can provide 160  
16 horsepower (119 kilowatts) at 20 miles to do work at that  
17 distance. No fluids are conducted down the interior of this  
18 umbilical generally designated by element 520 in  
19 Figure 21. This umbilical is also useful for other  
20 applications to be discussed later.

21  
22 Selecting different specific gravities for the  
23 pressure balanced silica microspheres in syntactic foam  
24 that fills the volume within the spoolable composite 518  
25 allows different preferred embodiments to be designed to be  
26 neutrally buoyant within different well fluids having  
27 different densities. As a practical matter, an umbilical  
28 having a particular density will be used within a range of  
29 acceptable densities of well fluids.

30  
31 Figure 22 is a schematic drawing that shows a ship  
32 performing subsea well servicing. Ship 522 in ocean 524  
33 possesses an umbilical carousel 526 having umbilical 528 that  
34 proceeds through lubricator 530 that houses Smart Shuttle

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1 532. Subsea well 534 on the ocean bottom 535 has mating  
2 equipment 536 that mates to mating equipment 538 of the  
3 lubricator 530. The lubricator is guided into place by  
4 remotely operated vehicle 540 obtaining its power and  
5 communications from umbilical 542. The umbilical carousel  
6 for umbilical 542 is not shown for simplicity.

7  
8 Upon entering the subsea well, the Smart Shuttle is to  
9 proceed through the base of the lubricator 544 and into the  
10 wellbore below (not shown in Figure 22). There, the Smart  
11 Shuttle is to perform a well workover that requires fluids to  
12 be injected into formation such as acids. Umbilical 528 may  
13 be selected to be a suitable umbilical including umbilical 2  
14 in Figure 1, and umbilical 492 in Figure 20. Equipment  
15 resembling what is shown in Figure 5 is on board the ship so  
16 that a computer system can control the workover operations.

17  
18 In this case, umbilical 542 need not provide fluids to  
19 the remotely operated vehicle 540. Therefore, umbilical 542  
20 may be chosen from umbilicals that includes umbilical 520 in  
21 Figure 21. Equipment resembling what is shown in Figure 5 is  
22 also onboard ship so that a computer system can control the  
23 remotely operated vehicle 540. The upper end of umbilical  
24 542 proceeding to its carousel is not shown on the left-hand  
25 side of Figure 22 for simplicity. In this case, the  
26 umbilical 542 is designed to have any desired buoyancy in sea  
27 water, that specifically includes densities greater than sea  
28 water, as is conventional in the industry. The apparatus and  
29 methods to control the power and communications is similar to  
30 that shown in Figures 2, 3, 4 and 5 and will not be repeated  
31 here for the purpose of brevity. In one preferred  
32 embodiment, over 60 kilowatts of power is provided by  
33 umbilical 542 to remotely operated vehicle 540. This power  
34 is provided to the load of the remotely operated vehicle,

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1 which in several preferred embodiments, is an electric motor  
2 that drives a propeller that provides thrust for the remotely  
3 operated vehicle. For simplicity, Figure 22 does not show a  
4 free floating remotely operated vehicle (ROV) tethered to the  
5 ship by a free floating umbilical.

6  
7 **Figure 23** is a schematic drawing similar to Figure 22.  
8 Figure 23 also shows a ship performing subsea well servicing.  
9 Ship 546 in ocean 548 possesses a first umbilical carousel  
10 550 (not shown in Figure 23 for simplicity) having umbilical  
11 552 that proceeds through lubricator 554 that houses Smart  
12 Shuttle 556. Subsea well 558 on the ocean bottom 560 has  
13 mating equipment 562 that mates to mating equipment 564 of  
14 the lubricator 554. The lubricator is guided into place by  
15 first remotely operated vehicle 566 that obtains its power  
16 and communications from umbilical 568 that is deployed from  
17 second umbilical carousel 570 (not shown in Figure 23 for  
18 simplicity). In this case, the umbilical 568 is designed to  
19 have any desired buoyancy in sea water, that specifically  
20 includes densities greater than sea water as is conventional  
21 in the industry. The upper end of umbilical 568 proceeding  
22 to carousel 570 near the top of the crane on the right-hand  
23 side of Figure 23 is not shown for simplicity.

24  
25 Upon entering the subsea well, the Smart Shuttle is to  
26 proceed through the base of the lubricator 572 and into the  
27 wellbore below (not shown in Figure 22). There, the Smart  
28 Shuttle is to perform a well workover that does not  
29 necessarily require fluids to be injected into formation.  
30 Therefore, umbilical 552 may be selected to be a suitable  
31 umbilical including umbilical 520 in Figure 21. Equipment  
32 resembling what is shown in Figure 5 is on board the ship so  
33 that a computer system can control the Smart Shuttle, and any  
34

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1 equipment attached to the Smart Shuttle, during workover  
2 operations.

3  
4 In this case, umbilical 568 need not provide fluids to  
5 first remotely operated vehicle 566. Therefore, umbilical  
6 568 may be chosen from umbilicals that includes umbilical  
7 520 in Figure 21. Equipment resembling what is shown in  
8 Figure 5 is also onboard ship so that a computer system can  
9 control first remotely operated vehicle 566. In this case,  
10 the umbilical 568 is designed to have any desired buoyancy in  
11 sea water, that specifically includes densities greater than  
12 sea water as is conventional in the industry. The apparatus  
13 and methods to control the power and communications to first  
14 remotely operated vehicle are similar to that shown in  
15 Figures 2, 3, 4 and 5 and will not be repeated here for the  
16 purpose of brevity.

17  
18 Figure 23 shows second remotely operated vehicle 574  
19 that obtains its power and communications from umbilical 576  
20 that is deployed from third umbilical carousel 578 (not shown  
21 in Figure 23 for simplicity). Second remotely operated  
22 vehicle 574 is to suitably attach to the subsea well 558 and  
23 is to remove fluids from the wellbore. Therefore, umbilical  
24 576 may be selected to be a suitable umbilical including  
25 umbilical 2 in Figure 1 and umbilical 492 in Figure 20.  
26 The upper end of umbilical 576 proceeding to carousel 578  
27 near the top of the crane on the left-hand side of  
28 Figure 23 is not shown for simplicity. Equipment resembling  
29 what is shown in Figure 5 is on board the ship so that a  
30 computer system can control the operation of second remotely  
31 operated vehicle 574. In this case, the umbilical 576 is  
32 designed to have any desired buoyancy in sea water, that  
33 specifically includes densities greater than sea water as is  
34 conventional in the industry. In one preferred embodiment,

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1 over 60 kilowatts of power is provided by umbilical 576 to  
2 remotely operated vehicle 574. This power is provided to the  
3 load of the remotely operated vehicle, which in several  
4 preferred embodiments, is an electric motor that drives a  
5 propeller that provides thrust for the remotely operated  
6 vehicle. In other embodiments, this power is provided to an  
7 electric motor that drives a downhole pump. For simplicity,  
8 Figure 23 does not show a free floating remotely operated  
9 vehicle (ROV) tethered to the ship by a free floating  
10 umbilical.

11  
12 In Figures 22 and 23, the feedback control of the  
13 voltage, RPM, current, and other parameters of an electric  
14 motor within an remotely operated vehicle is accomplished by  
15 analogy to that disclosed in relation to the electric motor  
16 of the subterranean electric drilling machine. In the  
17 interests of brevity, this feedback control of remotely  
18 operated vehicles will not be further discussed.

19  
20 **Figure 24** shows one embodiment of the Smart Shuttle™  
21 generally designated with the numeral 580 that is located  
22 within a "pipe means" 582 that includes a casing, drill pipe,  
23 tubing, etc. The Smart Shuttle is comprised of a progressive  
24 cavity pump 584 that has a rotor 586 and stator 588 as is  
25 typical of such pumps. The progressive cavity pump is  
26 coupled to gear box 590 that is in turn coupled to the  
27 electrical submersible motor 592, which in turn is connected  
28 to electronics assembly 594 having any downhole computer, the  
29 downhole sensors, and communications system, which in turn is  
30 connected by the quick change collar 596 to the umbilical  
31 head 598 that is connected the umbilical 600.

32  
33 The lower wiper plug assembly 602 has sealing lobe 604  
34 and this assembly is firmly attached to the body of the

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1 progressive cavity pump at the location shown in  
2 Figure 24. Lower wiper plug assembly has lower bypass  
3 passage 606 which has electrically operated valves 608 and  
4 610. The upper wiper plug assembly 612 has sealing lobe 614  
5 and this assembly is firmly attached to the sections of the  
6 apparatus having the gear box and the electrical submersible  
7 motor at the location shown in Figure 24. The upper wiper  
8 assembly also has permanently open upper bypass port 616 in  
9 the embodiment shown in Figure 24.

10  
11 In terms of Figure 24, and when the electrical  
12 submersible motor is suitably turning the rotor of the  
13 progressive cavity pump (PCP), a volume of fluid  $\Delta V_2$  per unit  
14 time in the wellbore is pumped into the lower side port 618  
15 of the PCP and out of the upper side port 620 of the PCP.  
16 With valves 608 and 610 closed, the fluid  $\Delta V_2$  is then forced  
17 through the upper bypass port 616 into the portion of the  
18 well above the upper surface of the upper wiper plug  
19 assembly. In this manner, the Smart Shuttle is then forced  
20 downward into the wellbore. The Retrieval Sub 620 is  
21 attached to the body of the Smart Shuttle by quick change  
22 collar 622 that in turn is connected to the lower body of the  
23 progressive cavity pump. This, and related embodiments of  
24 the Smart Shuttle is used to transport equipment attached to  
25 the Retrieval Sub into wells and out of wells. The Smart  
26 Shuttle is an example of a "well conveyance means", or  
27 simply, a "conveyance means". Fluid conduction means 624 is  
28 able to conduct any fluids available from umbilical 600  
29 through the Retrieval Sub 620, although that fluid conduction  
30 means 624 is not shown in Figure 24 for simplicity. Fluid  
31 conduction means 624 is fabricated using tubing and  
32 technology currently available in the oil and gas industry.

33  
34  
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1           **Figure 25** shows another well conveyance means.  
2   Umbilical 626 possesses one or more electrical conductors.  
3   In several preferred embodiments, umbilical 626 possesses one  
4   or more high power electrical conductors. Umbilical head 628  
5   connects the umbilical to tractor conveyor 630. The tractor  
6   conveyor has at least one friction wheel 632 which engages  
7   the interior of pipe 634. The tractor conveyor has four  
8   friction wheels as shown in Figure 25. Quick change collar  
9   assembly 635 connects the tractor conveyor to the Retrieval  
10   Sub 636.

11  
12           The tractor conveyor 630 with its Retrieval Sub 636  
13   installed in Figure 25 is an example of a "tractor conveyance  
14   means", a "tractor deployer", or a "downhole tractor  
15   deployment device". Electrical energy delivered via the  
16   umbilical to the tractor conveyor is used to drive electrical  
17   motors and/or electro-hydraulic systems 637 to provide  
18   rotational energy to the friction wheels (although the  
19   details of element 637 are not shown in Figure 25 for  
20   simplicity). That rotational energy causes the tractor  
21   conveyor to move within the well.

22  
23           The tractor conveyance means in Figure 25 provides  
24   similar operational features as different embodiments  
25   previously described heretofore as Smart Shuttles. Fluid  
26   conduction means 638 is able to conduct any fluids available  
27   from umbilical 626 through the Retrieval Sub 636, although  
28   that fluid conduction means 638 is not shown in Figure 24 for  
29   simplicity. Fluid conduction means 638 is fabricated using  
30   tubing and technology currently available in the oil and gas  
31   industry.

32  
33           By analogy with the Smart Shuttle, one embodiment of  
34   the tractor conveyance means may be used as a portion of an

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1 "automated well drilling and completion system". As  
2 described herein, this automated system is called the  
3 "tractor conveyance system" or the "automated tractor  
4 conveyance system". The tractor conveyance means is  
5 substantially under the control of a computer system that  
6 executes a sequence of programmed steps that has at least one  
7 computer system located on the surface of the earth and has  
8 means to convey at least one completion device attached to  
9 the Retrieval Sub into the wellbore under the automated  
10 control of the computer system. The automated system has at  
11 least one sensor means located within the tractor conveyance  
12 means, has first communications means that provides commands  
13 from the computer system to the tractor conveyance means, has  
14 second communications means that provides information from  
15 the sensor means to the computer system, where the execution  
16 of the programmed steps of the computer system to control the  
17 tractor conveyance means takes into account information  
18 received from the sensor means to optimize the steps executed  
19 by the computer system to drill and complete the well.

20  
21 The Retrieval Sub can be attached to a number of the  
22 devices shown in **Figure 26**. Those devices include any  
23 commercial tool or device 640; any logging tool 642; any  
24 torque reaction centralizer 644; any scraper 646; any  
25 perforating tool 648; any flow meter 650; any Downhole Rig  
26 with rotary bit 652; any Universal Completion Device™ 654;  
27 any straddle packer 656; any injection tool 658; any oil/gas  
28 separator 660; any flow line cleaning tool 662; any casing  
29 expanding tool 664; any plug 666; any valve 668; and any  
30 locking mechanism 670. These different tools are either  
31 defined in applicant's applications or are tools used in the  
32 oil and gas industry. The point is that any of these devices  
33 can be attached to the Retrieval Sub of the Cased Hole Smart  
34 Shuttle 672 or to the Retrieval Sub of the Open Hole Smart

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1 Shuttle 674. These devices may similarly be attached to the  
2 Retrieval Sub of the tractor conveyance means. Each such  
3 device in this paragraph may be called a "completion device"  
4 and collectively, these may be referenced as "completion  
5 devices".  
6

7 These devices specified in the previous paragraph may be  
8 used for a variety of different purposes in the oil and gas  
9 industry. Many of those tools can be used to serve wells.  
10 Please refer to Figure 27 that shows a diagrammatic  
11 representation of functions that may be performed with the  
12 Smart Shuttle or the Well Locomotive. Figure 27 shows that  
13 the Smart Shuttle or the Well Locomotive shown  
14 diagrammatically as element 676 may be used for the purposes  
15 of completion 678 (ie., to perform completion services  
16 on a well); production & maintenance 680 (ie., to perform  
17 production and maintenance services on a well); enhanced  
18 recovery 682 (ie., to perform enhanced recovery services on a  
19 well); and for drilling 684. Under completion functions, or  
20 "completion services", the Smart Shuttle and Well Locomotive  
21 may be used for the completion of extended reach lateral  
22 wells 686; for logging and perforating 688; for stimulation  
23 and fluid services 690; may be used to install the Universal  
24 Completion Device™ 692; and may be used to install completion  
25 hardware such as plugs, valves, gages, etc. 694. Under  
26 production and maintenance functions, or "production and  
27 maintenance services", the Smart Shuttle and Well Locomotive  
28 may be used for flow assurance services 696; for maintenance  
29 and repair 698; for workovers, that include logging,  
30 perforating, etc., 700; and for reservoir monitoring and  
31 control 702. Under enhanced recovery functions, or "enhanced  
32 recovery services", the Smart Shuttle and Well Locomotive may  
33 be used for recompletions, well extensions, and laterals 704;  
34 to install downhole separators 706; to perform artificial

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1 lift 708; to facilitate downhole injection 710; and for fluid  
2 services 712. Under drilling functions, or under "drilling  
3 services", the Smart Shuttle and the Well Locomotive may be  
4 used for casing drilling purposes 714; for liner drainhole  
5 drilling purposes 716; for coiled tubing drilling 718; and  
6 for extended reach lateral drilling 720. Extensive details  
7 are provided in about each of these functions in the related  
8 U.S. Disclosure Documents and in the related Provisional  
9 Patent Applications cited above.

10  
11 Any one or more of the functions provided in the  
12 previous paragraph is called a "well service". Two or more  
13 of such functions are called "well services". The execution  
14 of the programmed steps of the automated computer system to  
15 control the Smart Shuttle™, or tractor conveyance means,  
16 takes into account information received from the sensor means  
17 within the tractor conveyance means to optimize the steps  
18 executed by the computer system to service the well.

19  
20 The above umbilicals have stated calculations pertaining  
21 to lengths of 20 miles. However, the umbilicals can be any  
22 length from 100's of feet to 20 miles. The extreme distance  
23 of 20 miles was chosen to show neutrally buoyant umbilicals  
24 can provide high power and high speed data communications at  
25 great distances that has heretofore not been recognized in  
26 the oil and gas industry.

27  
28 As stated previously, the phrase "substantially  
29 neutrally buoyant", "essentially neutrally buoyant", "near  
30 neutral buoyant", and "approximately neutrally buoyant" may  
31 be used interchangeably. In several preferred embodiments of  
32 the invention, the meaning of these terms is that in the  
33 presence of the well fluids, that the buoyancy of the  
34

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1 umbilical causes the typical friction of the umbilical  
2 against the well to be substantially reduced.

3  
4 As stated earlier, the tractor conveyor tractor conveyor  
5 630 with its Retrieval Sub 636 in Figure 25 is an example of  
6 a "conveyance means", a "tractor conveyance means", a  
7 "tractor deployer", or a "downhole tractor deployment  
8 device". There are many "well tractors", or devices related  
9 to well tractors, a selection of which are described in the  
10 following documents: U.S. Patent Nos. 6,347,674; 6,345,669;  
11 6,318,470; 6,296,066; 6,273,189; 6,257,332; 6,241,031;  
12 6,241,028; 6,225,719; 6,179,058; 6,179,055; 6,173,787;  
13 6,089,323; 6,082,461; 5,954,131; 5,794,703; 5,547,314;  
14 5,375,668; 5,209,304; 5,184,676; 5,121,694; 5,018,451;  
15 5,040,619; 4,960,173; 4,686,653; 4,643,377; 4,624,306;  
16 4,570,709; 4,463,814; 4,243,099; 4,192,380; 4,085,808;  
17 4,071,086; 4,031,750; 3,969,950; 3,890,905; 3,888,319;  
18 3,827,512; in EP0564500B1; and in WO9806927; WO9521987;  
19 WO9318277; and WO9116520; entire copies of which are  
20 incorporated herein by reference. Entire copies of the 39  
21 cited references in this paragraph are incorporated herein by  
22 reference. Many of these devices are means to cause or  
23 generate movement within wellbores. Such "movement means"  
24 may be attached to a device similar to the Retrieval Sub 636.  
25 Devices similar to Retrieval Sub 636 are called "retrieval  
26 means". So, movement means may be coupled to retrieval means  
27 to make a "tractor conveyance means", or tractor deployers,  
28 or downhole tractor deployment devices.

29  
30 In view of the above, several embodiments of this  
31 invention use a closed-loop system to service a well for  
32 producing hydrocarbons from a borehole in the earth having at  
33 least one computer system located on the surface of the  
34 earth, which possess at least one conveyance means to convey

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1 at least one completion device into the borehole under the  
2 automated control of the computer system that executes a  
3 series of programmed steps, which possess at least one sensor  
4 means located within the conveyance means, which have first  
5 communications means that provides commands from the  
6 computer system to the conveyance means and possessing second  
7 communications means that provides information from the  
8 sensor means to the computer system, whereby the execution of  
9 the programmed steps by the computer system to control the  
10 conveyance means takes into account information received from  
11 the sensor means to optimize the steps executed by the  
12 computer to service the well. Such system is called a  
13 "closed-loop tractor conveyance system". The closed-loop  
14 system may also be used to monitor and control production of  
15 hydrocarbons from the wellbore.

16  
17 The above described umbilicals, and other variations of  
18 such umbilicals that meet the above defined operational  
19 specifications, could be manufactured on a contractual basis  
20 by a firm called ABB Offshore Systems that is located in  
21 Stavanger, Norway, that has its U.S.A. office that may be  
22 reached through ABB Offshore Systems, Inc., having the  
23 address of 8909 Jackrabbit Road, Houston, Texas 77095, having  
24 the telephone number of (281) 855-3200, that has its website  
25 that can be reached through [www.abb.com](http://www.abb.com). The above described  
26 umbilicals, and other variations of such umbilicals that meet  
27 the above defined operational specifications, might be  
28 manufactured on a contractual basis by a firm called the  
29 Fiberspar Corporation that may be reached at 28 Patterson  
30 Brook Road, West Warehan, Massachusetts 02576, having the  
31 telephone number (508) 291-9000, which has its website at  
32 [www.fiberspar.com](http://www.fiberspar.com). This firm is capable of supplying various  
33 spoolable composite tubes capable of being spooled onto a  
34 reel having relevant anisotropic characteristic, a specified

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1 burst pressure, a specified collapse pressure, a specified  
2 tensile strength, a specified compression strength, a  
3 specified load carrying capacity, which is also bendable.  
4 Some of these tubes include an inner liner material, an  
5 interface layer, fiber composite layers, a pressure barrier  
6 layer, and an outer protective layer. The fiber composite  
7 layers can have triaxial braid structure. The composites  
8 may be fabricated from carbon-based composites.

9  
10 In the above, syntactic foam materials were described in  
11 various preferred embodiments to change the apparent buoyancy  
12 of an umbilical in the presence of other surrounding fluids.  
13 However, any material of a different density may be used for  
14 this purpose.

15  
16 A preferred embodiment above has described an apparatus  
17 to drill oil and gas wells having subterranean electric  
18 drilling machine disposed in a wellbore such as that shown  
19 as element 94 Figure 6. The subterranean electric drilling  
20 machine possesses at least one downhole electric motor that  
21 is shown as element 114 in Figure 6. This electric motor  
22 rotates a rotary drill bit identified as elements 106, 110  
23 and 112 in Figure 6. This electric motor rotates the drill  
24 bit at a selected RPM determined by the frequency, current  
25 and voltage applied to input terminals of the electric motor  
26 as shown in Figure 2 and in Figure 3. One advantage of such  
27 an electrically operated drill bit operating at relatively  
28 high RPM is that it produces very fine rock cuttings that are  
29 easily transported to the surface by mud flow. The input  
30 terminals of the electric motor are identified as the inputs  
31 to the downhole electrical load 22 in Figure 2, which in  
32 several embodiments is an electric motor, which are also  
33 attached to the sensing unit 24. The input terminals of the  
34 electric motor are shown as the leads attached to either side

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1 of element 34 in Figure 2. The electric motor operates  
2 properly with a particular voltage level applied to its  
3 electrical input. Please refer to the preferred embodiment  
4 discussed in relation to electric motor 34 in Figure 3. It  
5 is important to note that in several preferred embodiments,  
6 the electrical motor 34 in Figure 3 is dissipating 160  
7 horsepower (119 kilowatts). A surface power supply means  
8 located on the surface of the earth provides a voltage output  
9 that is identified with element 20 in Figure 2. An umbilical  
10 means disposed in the wellbore surrounded by well fluids  
11 connecting the surface power supply means to the subterranean  
12 electric drilling machine provides electrical power to the  
13 electrical input of the electric motor. For example, such an  
14 umbilical means is shown as element 116 in Figure 6 and in  
15 Figure 9. The umbilical means possesses insulated electric  
16 wires as shown in Figures 1, and 20. The umbilical means  
17 possess high speed data communications means such as high  
18 speed data link 14 in Figure 1. The umbilical means  
19 possesses a fluid conduit for conveying drilling fluids  
20 through the interior of the umbilical means such as element 8  
21 in Figure 1 and 506 in Figure 20. The preferred embodiment  
22 has means to measure first voltage applied to the first  
23 electrical input of the electrical motor as shown by element  
24 24 in Figure 2. The preferred embodiment possesses means to  
25 transmit information related to the measured first voltage  
26 through a high speed data communications means within the  
27 umbilical to a computer located on the surface of the earth  
28 by using the high speed data link 14 in Figure 1. The  
29 embodiment further possesses computer controlled means to  
30 adjust the first voltage output as shown by element 28 in  
31 Figure 2. The computer system 26 in Figure 2 is used to  
32 maintain first voltage input at a particular voltage level to  
33 provide proper operation of the electric motor within the  
34 subterranean electric drilling machine.

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1           In several preferred embodiments, the electric  
2 motor 34 in Figure 3 dissipates in excess of 60 kilowatts.  
3 This is important because it is the recollection of the  
4 inventors that several scientists and senior managers of a  
5 major oil services company stated their opinions that it  
6 would be impossible to provide over 60 kilowatts to an  
7 electric motor, or any other electrical load, at distances of  
8 up to 20 miles from a wellsite through any type of reasonably  
9 sized umbilical that would be practical to use within  
10 wellbores. According to the recollection of the inventors,  
11 these senior managers and scientists clearly stated their  
12 opinions before the invention herein was disclosed to those  
13 particular individuals. Yet further from this recollection,  
14 it apparently never occurred to these same scientists and  
15 senior managers that any such umbilical delivering in excess  
16 of 60 kilowatts could also be neutrally buoyant. However,  
17 only after disclosure of the invention herein to those  
18 scientists and senior managers, did they apparently accept  
19 that such umbilicals could be designed and built.  
20 Accordingly, because the individuals involved are well known  
21 in the oil and gas industry, and are experts in fields  
22 directly pertaining to the invention, the preferred  
23 embodiment described herein is not obvious to one having  
24 ordinary skill in the art.

25  
26           Therefore, a preferred embodiment is an apparatus to  
27 drill oil and gas wells comprising:

28  
29       (a) a subterranean electric drilling machine disposed in a  
30 wellbore that possesses at least one electric motor that  
31 rotates a rotary drill bit at a selected RPM, whereby the  
32 electric motor possesses first electrical input, whereby the  
33 electric motor properly operates with a particular voltage  
34 level applied to first electrical input, and whereby the

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1 electric motor dissipates in excess of 60 kilowatts with the  
2 particular voltage level applied to the first electrical  
3 input;

4  
5 (b) surface power supply means located on the surface of the  
6 earth providing first voltage output;

7  
8 (c) umbilical means disposed in the wellbore surrounded by  
9 well fluids connecting the surface power supply means to the  
10 subterranean electric drilling machine that provides  
11 electrical power to the first electrical input of the  
12 electric motor, whereby the umbilical means possesses  
13 insulated electric wires, whereby the umbilical means  
14 possesses high speed data communications means, and whereby  
15 the umbilical possesses a fluid conduit for conveying  
16 drilling fluids through the interior of the  
17 umbilical means;

18  
19 (d) means to measure first voltage applied to the first  
20 electrical input of the electrical motor;

21  
22 (e) means to transmit information related to the measured  
23 first voltage through the high speed data communications  
24 means within the umbilical to a computer located on the  
25 surface of the earth;

26  
27 (f) computer controlled means to adjust the first voltage  
28 output so as to maintain first voltage input at the  
29 particular voltage level to provide proper operation of the  
30 electric motor within the subterranean electric drilling  
31 machine.

32  
33 Another preferred embodiment of the invention described  
34 in the previous paragraph provides an umbilical means that

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1 a approximately neutrally buoyant within the well fluids to  
2 reduce the frictional drag on the neutrally buoyant  
3 umbilical.

4  
5 In view of the above disclosure, yet another preferred  
6 embodiment is the method of feed-back control of an electric  
7 motor having at least one voltage input located within a  
8 subterranean electric drilling machine located in a borehole  
9 that dissipates at least 60 kilowatts that receives power  
10 from a surface power supply through an umbilical surrounded  
11 by well fluids that possesses at least two insulated electric  
12 wires, whereby the umbilical also possesses high speed data  
13 link for data communications, comprising the steps of:

14  
15 (a) measuring the voltage input to the electric motor;

16  
17 (b) sending information related to the measured voltage input  
18 through the high speed data link to a computer located on the  
19 surface of the earth; and

20  
21 (c) using the computer to adjust the voltage output of the  
22 surface power supply that is used to control the voltage  
23 input to the electrical motor.

24  
25 Another preferred embodiment of the invention described  
26 in the previous paragraph provides an umbilical that is  
27 a approximately neutrally buoyant within the well fluids to  
28 reduce the frictional drag on the umbilical.

29  
30 In view of the above disclosure, yet another preferred  
31 embodiment is the method of providing in excess of 60  
32 kilowatts of electrical power to the electrical motor of a  
33 subterranean electric drilling machine through a  
34 substantially neutrally buoyant composite umbilical

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1 containing electrical conductors to reduce the frictional  
2 drag on the neutrally buoyant umbilical.

3  
4 In view of the disclosure related to Figures 22 and 23,  
5 it is evident that the invention may be used to provide  
6 electrical power to an electric motor located within a  
7 remotely operated vehicle. Accordingly, a preferred  
8 embodiment of the invention provides a method of feed-back  
9 control of an electric motor having at least one voltage  
10 input located within a remotely operated vehicle that  
11 dissipates at least 60 kilowatts that receives power from a  
12 power supply located on a ship through an umbilical  
13 surrounded by sea water that possesses at least two insulated  
14 electric wires, whereby the umbilical also possesses high  
15 speed data link for data communications, comprising the  
16 steps of:

17  
18 (a) measuring the voltage input to the electric motor;

19  
20 (b) sending information related to the measured voltage input  
21 through the high speed data link to a computer located on the  
22 ship; and

23  
24 (c) using the computer to adjust the voltage output of the  
25 power supply located on the ship that is used to control  
26 the voltage input to the electrical motor.

27  
28 Accordingly, yet another preferred embodiment of the  
29 invention is the method of providing in excess of 60  
30 kilowatts of electrical power to the electric motor of a  
31 remotely operated vehicle through an umbilical containing  
32 electrical conductors and at least one high speed data  
33 communications means.

34  
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1           Several of the above preferred embodiments describe  
2 the Subterranean Electric Drilling Machine™, or simply the  
3 Subterranean Drilling Machine™ (SDM™), that performs  
4 Subterranean Electric Drilling™ (SED™) that is used to  
5 construct a Subterranean Electric Drilled Monobore Well™  
6 or an SED Monobore Well™. Several of the above preferred  
7 embodiments also describe the Subterranean Liner Expansion  
8 Tool™ (SLET™) otherwise called the Casing Expansion Tool™  
9 (CET™).

10  
11           **Figure 28** shows a fixed platform 800 penetrating ocean  
12 water 804 that is anchored in the ocean bottom at a  
13 particular location 808. Production flowline 812 and  
14 production flowline 816 carry oil and gas production to the  
15 fixed platform. Steel cased well 820 penetrates the ocean  
16 bottom at location 824 which is terminated in the first  
17 subsea Xmas Tree 828. Oil and gas production flows from the  
18 first Xmas Tree through jumper 832 to manifold 836. Oil and  
19 gas production flows from manifold 836 through flowlines 812  
20 and 816 to the TLP 800. Subsea control umbilical 840 is  
21 connected to mid-flowline tie-in manifold 844 for a second  
22 Xmas Tree that in turn is connected to subsea control  
23 umbilical 848 that proceeds to the Umbilical Termination  
24 Assembly ("UTA") 852. (The second Xmas Tree is not shown in  
25 Figure 28 for the purposes of simplicity.) Control signals  
26 are then sent through the Flying Leads, such as Flying Lead  
27 856, that in turn are connected to the first Xmas Tree to  
28 control well production. Mid-flowline tie-in manifold 844 is  
29 connected to jumper 860 that is connected to assembly 864.  
30 Oil and gas production also flows through flowline 868 to  
31 assembly 864 and through flowline 872 to the TLP.

32  
33           Installations such as shown in Figure 28 are typical in  
34 the Gulf of Mexico. Figure 28 shows a typical satellite

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1 field system. In some cases, the flowlines are single steel  
2 pipes, which are subject to wax build-up and to other  
3 blockage problems such as hydrates, scales or other solids  
4 forming from the production due to a loss in static pressure  
5 or in temperature, or to any other process or mechanism.  
6 In other cases, steel pipe-in-pipe systems with the outer  
7 pipe being externally insulated and hot water circulated  
8 through the annulus between the two pipes is used to heat the  
9 flowlines to avoid wax build-up and other blockage problems.

10  
11 In Figure 28, the "host" is illustrated as a fixed  
12 platform. However, many other "hosts" are possible including  
13 the following: an FPSO (a "Floating, Processing, Storage and  
14 Offloading" facility); all types floating platforms; Tension  
15 Leg Platforms ("TLP's"); SPARS; floating platforms with dry  
16 tree risers including TLP's and SPARS; etc. Here a SPAR is a  
17 floating moored structure for offshore drilling and/or  
18 production operations, which is typically a deep draft  
19 structure with very low motions due to the environment, and  
20 is especially suited for deepwater, and often supports dry  
21 surface trees. For the purposes of this invention, a  
22 "host" may include any of the previously listed structures  
23 associated with the formal definition of an "offshore  
24 platform" as defined above in quotes.

25  
26 **Figure 29** shows another "host" system. Figure 29 shows  
27 Floating Production, Storage, and Offloading structure (FPSO)  
28 876 loading crude through flexible line 880 to shuttle tanker  
29 884 located on ocean surface 888. This is a typical FPSO  
30 arrangement as used in offshore Brazil and West Africa.  
31 Mooring component 892 is anchored to the sea bottom at  
32 location 896. Mooring component 900 is anchored to sea  
33 bottom at location 904. Subsea wellhead 908 at location 912  
34 on the sea bottom passes crude production through flowline

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1 916 to the FPSO. Subsea wellhead 920 at location 924 on the  
2 sea bottom passes crude production through flowline 928 to  
3 the FPSO. Subsea wellhead 932 at location 936 on the sea  
4 bottom passes crude production through flowline 940 to the  
5 FPSO. Subsea wellhead 944 at location 948 on the sea bottom  
6 passes crude production through flowline 952 to the FPSO.  
7 Often, the flowlines are single pipes that are subject to  
8 blockage from wax and other substances.

9  
10 Another host is shown in Figure 30. Here floating  
11 platform 956 is shown floating in ocean 960 having ocean  
12 surface 964. Steel cased well 968 penetrates the sea bottom  
13 972 at location 974, and is attached to wellhead 976. Steel  
14 flowline 980 is attached to wellhead 976 and lies on sea  
15 bottom 972 for a distance until it raises off the sea bottom  
16 at position 984. The upper extremity of the flowline 988,  
17 also known as a riser, is connected to the floating platform,  
18 and the riser is suspended below the floating platform having  
19 a minimum radius of curvature R at location 992 shown in  
20 Figure 30.

21  
22 The Electric Flowline Immersion Heater Assembly  
23 ("EFIHA") is generally shown as element 996 in Figure 30.  
24 The EFIHA shown in Figure 30 possesses Electrically Heated  
25 Composite Umbilical ("EHCUC") 1000. The inside diameter of  
26 the steel flowline 980 is shown by the legend ID(FL) in  
27 Figure 30. The wall thickness of the steel flowline 980 is  
28 WT(FL), which is not shown in Figure 30 in the interests of  
29 brevity. The outside diameter of the EHCUC is shown by the  
30 legend OD(IH) in Figure 30. The wall thickness of the EHCUC  
31 is WT(IH), which is not shown in Figure 30 in the interests  
32 of brevity. Hydraulic seal 1004 is attached to the outside  
33 diameter of the EFIHA at location 1008. Hydraulic seal 1004  
34 may be comprised of multiple individual hydraulic sealing

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elements 1012, 1016, 1020, and 1024, which four elements are shown in Figure 30, but which are not so labeled in the interests of simplicity.

Hydraulic pressure may be generated with hydraulic equipment 1030 (not shown in the interests of simplicity in Figure 30) located on the floating platform 956. This hydraulic pressure may be applied to the annular space defined by the difference between the inside diameter of the flowline ID(FL) and the outside diameter of the EHCU that is OD(IH) that is shown as region 1034 in Figure 30. The hydraulic pressure applied in region 1034 in Figure 30 is defined as P(EFIHA). This pressure acts on the hydraulic seal 1004 that generates force F(EFIHA) which is applied to the EFIHA that is provided by the following equation:

$$F(EFIHA) = \pi \left\{ \left[ ID(FL)/2 \right]^2 - \left[ OD(IH)/2 \right]^2 \right\} \left\{ P(EFIHA) \right\}$$

Equation 2.

The force shown in Equation 2 is used to force the EFIHA down into the steel flowline. In one preferred embodiment of the invention, if wellhead 976 is set by control means 1038 so that no fluid may flow back into the well, then when the EFIHA is forced downward into the well by hydraulic force F(EFIHA), any displaced fluid in the sealed system flows up the inside of the EFIHA through region 1042 within the EFIHA and to the floating platform at location 1046. This is called "backflow" within the EFIHA. So, in this case, the displaced fluid flows up the interior of the F(EFIHA) to the floating platform.

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1           The EFIHA also possesses additional centralizing and  
2   hydraulic sealing elements 1048 and 1052. Instrumentation  
3   assembly and control assembly 1056 provides measurements of  
4   the ambient well conditions such as the pressure P(EFIHA),  
5   temperature (EFIHA), the depth, etc. The force used to drive  
6   the EFIHA into the well results in a downward velocity  
7   V(EFIHA) that may be a function of time. This downward  
8   velocity V(EFIHA) influences the pressure P(EFIHA). The  
9   force F(EFIHA) is adjusted so that the pressure P(EFIHA) does  
10   not exceed some predetermined maximum pressure P(EFIHA-MAX).  
11   The Electrically Heated Composite Umbilical ("EHCUC") 1000  
12   possesses internal electric heater wires, wires to power the  
13   instrumentation and control assembly 1056, means for high  
14   speed bidirectional communications, and power wires for any  
15   other services or purposes. As one example, wires 494 and  
16   496 in the umbilical shown in Figure 20 may be used instead  
17   as electrical resistors to generate heat to heat the EHCUC.  
18   In this case, the heat delivered to the EHCUC is equal to the  
19   following:

$$H(EHCUC) = [ I(EHCUC) ]^2 R(EHCUC)$$

Equation 3.

27           Here, H(EHCUC) is the power in watts ("heat") delivered  
28   to the EHCUC, the symbol I is the time averaged electrical  
29   current flowing through wires 494 and 496 in Figure 20, and  
30   R(EHCUC) is the combined series resistance of wires 494  
31   and 496. The current I is caused to flow through the  
32   resistors by a power supply that is not shown for simplicity.

33  
34  
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1           Instrumentation and control assembly 1056 may be used to  
2 sense the depth of the EHCU and the distance between the end  
3 of the EHCU and the wellhead shown by the legend Z(IH) .  
4 In one preferred embodiment of the invention, when Z(IH)  
5 reaches a predetermined value, then at least one hydraulic  
6 locking mechanism (not shown in Figure 30 for simplicity)  
7 within instrumentation and control assembly 1056 may be used  
8 to lock the EHCU into place within the well.

9  
10           In one preferred embodiment of the invention, when it is  
11 time to retrieve the EHCU, and with wellhead 976 is set by  
12 control means 1038 so that no fluids may flow into the  
13 wellhead, then pressuring up the interior of region 1042 will  
14 apply pressure to the downhole side of seal 1004 and force  
15 the EHCU towards the floating platform 956 and out of the  
16 well. Suitable spooling and handling equipment for the EHCU  
17 are provided on the floating platform 988 which are not shown  
18 in Figure 30 in the interests of simplicity. In another  
19 preferred embodiment, the EHCU is simply pulled out of the  
20 well by the spooling and handling equipment.

21  
22           In another preferred embodiment, and after the EFIHA is  
23 locked in place within the well, a cross-over valve 1055 (not  
24 shown in Figure 30 for simplicity) can be located at location  
25 1058 which location is towards the floating platform from the  
26 position of seal 1004. When production is allowed to flow to  
27 the floating platform, this cross-over valve can be set to  
28 any one of three states ("State 1", "State 2", and  
29 "State 3"). In State 1, oil and gas production would proceed  
30 through the interior of EHCU to the floating platform.  
31 For example, in State 1, oil and gas production would flow  
32 through region 1057 of the EHCU that is located towards the  
33 floating platform from seal 1004. In State 2, oil and gas  
34 production would flow through region 1058 located between the

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1 outside diameter of the EHCUC and the inside diameter of the  
2 flowline. State 2 has the advantage that all the heat  
3 generated in the EHCUC is transferred to the surrounding  
4 production. In State 3, the oil and gas production would  
5 flow through both regions 1057 and 1058 simultaneously.  
6 There are many variations of the invention.  
7

8 The next 12 paragraphs are paraphrased from page 66,  
9 line 41, to page 68, line 38, of Serial No. 09/487,197, now  
10 U.S. Patent 6,397,946 B1, that issued on June 4, 2003, having  
11 the inventor of William Banning Vail III, that was  
12 incorporated entirely by reference in co-pending  
13 Serial No. 10/223,025, having the Filing Date of 8/15/2002,  
14 that is entitled "High Power Umbilicals for Subterranean  
15 Electric Drilling Machines and Remotely Operated Vehicles".  
16 These 12 paraphrased paragraphs originally related to  
17 Figure 23 in U.S. Patent 6,397,946, but now relate to  
18 **Figure 31** herein. In Figure 23 in U.S. Patent 6,397,946 B1,  
19 a coiled tubing was conveyed downhole. In Figure 31 herein,  
20 an Electric Flowline Immersion Heater Assembly ("EFIHA")  
21 having an electrically heated composite umbilical ("EHCUC") is  
22 conveyed into a flowline. In addition, an extra "0" was  
23 added to all numerals that appeared in the corresponding text  
24 of U.S. Patent No. 6,397,946 B1, so for example element 780  
25 in Figure 23 in U.S. Patent No. 6,397,946 is now labeled as  
26 element 7800 in Figure 31 herein.  
27

28 However, the Smart Shuttles may be conveyed downhole  
29 with an attached Electric Flowline Immersion Heater Assembly  
30 ("EFIHA") having an electrically heated composite umbilical  
31 ("EHCUC") that is conveyed into a flowline. Such a Smart  
32 Shuttle with Retrieval Sub that is conveyed downhole that is  
33 attached to an EHCUC is shown in Figure 31 herein. In several  
34 preferred embodiments of the invention, the EHCUC conveyed by

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1 the Smart Shuttle into the flowline as shown in Figure 31 may  
2 be forced into the flowline by three different mechanisms:  
3 (a) by using mechanical "injectors" at the surface to force  
4 the coiled tubing downward into the flowline; (b) the PCP/ESM  
5 assembly may be used to assist by "pulling" the Smart Shuttle  
6 into the flowline; and (c) yet further, hydraulic forces on  
7 fluids from the surface may also force the Smart Shuttle into  
8 the flowline. That these three independent methods may be  
9 used to force the Smart Shuttle with its attached Retrieval  
10 Sub downward into the flowline will become better apparent  
11 with the following description of the elements in Figure 31.  
12

13 Most of the elements in Figure 31 through element 7200  
14 have been previously described in relation to Figure 23 in  
15 U.S. Patent 6,397,946 B1. The Progressive Cavity Pump is  
16 labeled with element 6800. The Progressive Cavity Pump is  
17 coupled to gear box 6830 that is in turn coupled to the  
18 Electrically Submersible Motor 6840, which in turn is  
19 connected to electronics assembly 6850 having any downhole  
20 computer, sensors, and communications system, which in turn  
21 is connected to the quick change collar 7700. The assembly  
22 below the quick change collar in Figure 31 is often referred  
23 to as the Progressive Cavity Pump/Electrical Submersible  
24 Motor assembly that is abbreviated as the "PCP/ESM assembly".  
25 Therefore, the "PCP/ESM assembly" is attached to the quick  
26 change collar 7700 in Figure 31.  
27

28 In Figure 31, an Electric Flowline Immersion Heater  
29 Assembly ("EFIHA") that is generally shown as numeral 7722  
30 has an Electrically Heated Composite Umbilical ("EHCU") 7724  
31 that is conveyed into steel flowline 6782. Tubing  
32 Termination Assembly 7780 has threads 7800 that mate to the  
33 threaded end 7762 of EHCU 7724. So, the Tubing Termination  
34 Assembly is inserted into the flowline and is attached to the

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1 threaded end 7762 of the EHCU 7724. In one preferred  
2 embodiment, any fluids that flow into, or out of, the EHCU  
3 are conducted to, and from, the interior of the flowline  
4 through fluid channel 7820. Valve 7832 located within fluid  
5 channel 7820 can be used to cut off any fluid flow through  
6 the channel. Valve 7832 may be open or closed as desired.  
7 For many of the following preferred embodiments, it is  
8 assumed that this valve 7832 is open unless explicitly stated  
9 otherwise. The wireline 7742 is connected to top submersible  
10 plug 7840 that connects to lower submersible plug 7860 which  
11 in turn passes the electrical conductors from the wireline to  
12 the quick change collar. The bundle of electrical conductors  
13 passing to the quick changer collar is designated with the  
14 numeral 7880 in Figure 31. Within the quick change collar is  
15 yet another electrical plug assembly that provides power and  
16 electrical signals through a bundle of wires to the "PCP/ESM  
17 assembly" that is not shown in Figure 31 solely for the  
18 purposes of simplicity. Typical design and assembly  
19 procedures used in the industry are assumed throughout this  
20 specification. It is often the case that a quick change  
21 collar surrounds male and female mating electrical  
22 connectors, which is typically the case in "logging tools"  
23 used in the wireline logging industry. Those connectors mate  
24 at the location specified by the dashed line 7890 shown on  
25 the interior of the quick change collar in Figure 31.

26  
27 In addition, the Tubing Termination Assembly 7780 also  
28 possesses expandable packer 7900. Upon command from the  
29 surface, this expandable packer can be inflated within the  
30 flowline to seal against the flowline as may be required  
31 during typical well completion procedures, and typical  
32 workover procedures, that are used in the industry. This  
33 expandable packer can also be used for a second purpose of  
34 forcing the Smart Shuttle into the wellbore as described

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1 below. This packer can also be used for additional purposes  
2 as described below.

3  
4 With reference to Figure 31, the Smart Shuttle may  
5 be forced downhole by three mechanisms that are described  
6 in separate paragraphs as follows.

7  
8 In a first preferred embodiment of the invention,  
9 mechanical "injectors" at the surface are used to force the  
10 Electric Flowline Immersion Heater Assembly ("EFIHA") 7722  
11 and its electrically heated composite umbilical ("EHCUC") 7724  
12 into the flowline 6782. These mechanical "injectors" were  
13 previously described in U.S. Patent No. 6,397,946 B1, an  
14 entire copy of which is incorporated herein by reference.

15  
16 In a second preferred embodiment of the invention,  
17 the electrically energized Progressive Cavity Pump forces  
18 fluid ΔV2 into the lower side port 7120 of the PCP and out of  
19 the upper side port 7140 of the PCP, and the Smart Shuttle is  
20 conveyed downhole. If this method is used by itself, and if  
21 expandable packer 7900 is in its deflated state as shown by  
22 the solid line in Figure 31, then no fluid would necessarily  
23 flow to the surface through fluid channel 7820. It could,  
24 but it is not necessary in this embodiment, and under the  
25 circumstances described.

26  
27 In a third preferred embodiment of the invention, and in  
28 analogy with the pump-down single zone packer apparatus 658  
29 described in Figure 17 in U.S. Patent No. 6,397,946 B1, the  
30 expandable packer 7900 in Figure 31 is inflated so as to make  
31 a reasonable seal against the flowline 6782, but not so  
32 firmly so as to lock the device in place. In Figure 31, the  
33 solid line labeled with numeral 7900 shows the uninflated  
34 state of the expandable packer, and the dotted line shows the

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1 expanded, or inflated, state of expandable packer 7900.  
2 Then, in analogy with fluid flow described in Figure 17 of  
3 U.S. Patent No. 6,387,946 B1, fluid forced into the upper  
4 flowline in annular region 7726 will force the apparatus  
5 attached to the expandable packer downward into the wellbore,  
6 and any fluid  $\Delta V_3$  displaced is forced upward through fluid  
7 channel 7820 and into the interior of the EHCU 7728 which in  
8 turn flows to the surface in analogy with previous  
9 description of fluid flow through coiled tubing to the  
10 surface in relation to Figure 17 in U.S. Patent 6,397,946.  
11 This of course assumes that valve 7832 is open.  
12

13 In principle, all first, second, and third methods of  
14 conveyance downhole can be used simultaneously, provided that  
15 valves 6980 and 7000 are set in their appropriate positions  
16 for the applications, provided that valve 7832 is set in its  
17 appropriate position, and provided the Progressive Cavity  
18 Pump 6800 is suitably energized.  
19

20 For simplicity, the particular embodiment of the  
21 invention shown in Figure 31 will be called in certain  
22 portions of the text that follows the "Electric Flowline  
23 Immersion Heater Assembly with Wireline Smart Shuttle"  
24 abbreviated "EFIHAWWSS" that is generally designated as  
25 numeral 7922 in Figure 31.  
26

27 Any smart completion device may be attached to the  
28 Retrieval Sub 7180 during any such conveyance downhole. For  
29 example, a casing saw or another packer can be installed on  
30 the Retrieval Sub so that many different services can be  
31 performed during one trip downhole. The casing saw and  
32 packers are described in U.S. Patent No. 6,397,946 B1. These  
33 include perforating, squeeze cementing, etc. - in fact many  
34 of the methods to complete oil and gas wells defined in

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1 the book entitled "Well Completion Methods", "Well Servicing  
2 and Workover", Lesson 4, from the series entitled "Lessons in  
3 Well Servicing and Workover", Petroleum Extension Service,  
4 The University of Texas at Austin, Austin, Texas, 1971, an  
5 entire copy of which is incorporated herein by reference.  
6

7 In another preferred embodiment of the invention, the  
8 apparatus in Figure 31 may be used to test production, or to  
9 assist production if it is used in another manner. In this  
10 embodiment, an electrically actuated production flowline lock  
11 7940 (not shown in Figure 31) is attached to the Retrieval  
12 Sub 7180. It has passages through it so that hydrocarbons  
13 below it can pass through it if necessary, but it otherwise  
14 locks the apparatus in Figure 31 to the inside of the casing.  
15 Once locked in place, the PCP/ESM assembly can pump  
16 hydrocarbons through lower side port 7120 of the PCP and out  
17 of the upper side port 7140 of the PCP. Thereafter,  
18 hydrocarbons are pumped through fluid channel 7820 of the  
19 Tubing Termination Assembly 7780 in Figure 31 provided that  
20 the expandable packer 7900 is suitably inflated. There are  
21 many variations on this particular embodiment of the  
22 invention but they are not further described here solely in  
23 the interests of brevity. With this embodiment, and with the  
24 PCP forcing fluids up the inside of the EHCU, then this  
25 provides a method of artificial lift for the produced  
26 hydrocarbons.  
27

28 Figure 31 also shows the Retrieval Sub electrical  
29 connector 3130, the rotor 6810 of the Progressing Cavity  
30 Pump, and the stator 6820 of the Progressing Cavity Pump.  
31 The Retrieval Sub 7180 is attached to the body of the Smart  
32 Shuttle by quick change collar 7200 that in turn is connected  
33 to the lower body of the Progressive Cavity Pump.  
34 The lower wiper plug assembly 6920 has sealing lobe 6940 and

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1 this assembly is firmly attached to the body of the  
2 Progressive Cavity Pump at the location generally specified  
3 by numeral 6960 and this assembly further has lower bypass  
4 passage 6980 which has electrically operated valves 7000 and  
5 7020. In Figure 31, the Smart Shuttle is comprised of the  
6 Progressing Cavity Pump 6800 and the wiper plug assembly  
7 6920.

8  
9 Figure 31 may be used to illustrated yet other preferred  
10 embodiments of the invention. The region of the well below  
11 the lower wiper plug assembly 6920 is designated by element  
12 6802. The annular region of the well between the lower wiper  
13 plug assembly 6920 and the inflatable packer 7900 is  
14 designated by element 6804. The annular region of the well  
15 above the inflatable packer has already been designated by  
16 numeral 7726. In another preferred embodiment of the  
17 invention, the PCP may be used to pump fluids from region  
18 6802 to region 6804. In this embodiment, valve 7832 is  
19 closed and the inflatable packer 7900 is in its uninflated  
20 state that is shown by the solid line in Figure 31. In this  
21 embodiment, hydrocarbons produced from the well will be  
22 pumped to the surface through region 7726 of the well. In  
23 this case, the EHCU will heat the hydrocarbons to prevent any  
24 build up of wax, hydrates, or other blockage substances in  
25 the well. In yet another preferred embodiment of the  
26 invention, valve 7830 may also be left open, and in such case  
27 produced hydrocarbons would not only flow through region 7726  
28 to the surface but also within the EHCU 7728 to the surface.

29  
30 In Figure 32, all the elements have been described  
31 except elements 7723, 7725, 7764, 7842, 7862, 7924, 8000, and  
32 8010. In Figure 32, there is no wireline within the  
33 Electrically Heated Composite Umbilical ("EHCU") 7725. In  
34 Figure 32, an Electric Flowline Immersion Heater Assembly

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1 ("EFIHA") is generally shown as numeral 7723 having an  
2 Electrically Heated Composite Umbilical ("EHCUC") 7725 that is  
3 conveyed into steel flowline 6782. Tubing Termination  
4 Assembly 7780 has threads 7800 that mate to the threaded end  
5 7764 of EHCUC 7725. Element 7924 in Figure 32 generally  
6 designates the Smart Shuttle Conveyed Electric Flowline  
7 Immersion Heater Assembly ("SSCEFIHA") disposed within the  
8 flowline 6782.

9  
10 The EHCUC 7725 possesses electrical heater wires, power  
11 cables, any hydraulic tubes, fiber-optic cables, etc. within  
12 the wall thickness of the EHCUC. The wall thickness of the  
13 EHCUC is defined by the legend "WT(EHCUC)", although that  
14 legend is not shown in Figure 32 for the purposes of  
15 simplicity. Assembly 8000 provides means to pass the heater  
16 wires, power cables, any hydraulic cables, fiber-optic  
17 cables, etc. from within the wall thickness of the EHCUC to  
18 jumper 8010 that connects to connector 7842 that in turn  
19 mates to connector 7862.

20  
21 In Figure 32, the Smart Shuttle is comprised of the  
22 Progressing Cavity Pump 6800 and the wiper plug assembly  
23 6920. In one mode of operation of a preferred embodiment,  
24 fluid is pumped from the bottom side of the wiper plug  
25 assembly to the top side of the wiper plug assembly, and with  
26 expandable packer 7900 in the collapsed position shown in  
27 Figure 32, the Smart Shuttle will convey the Electric  
28 Flowline Immersion Heater Assembly ("EFIHA") 7723 down into  
29 flowline 6782 (provided valve 7832 is open, and valves 6980  
30 and 7000 are closed).

31  
32 Figure 33 is similar to Figure 32, except here,  
33 expandable packer 7900, is in its extended position and makes  
34 contact with the interior wall of the flowline that is shown

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1 by the expanded solid line that is shaded. In this case,  
2 fluid pressure P provided to annular region 7726 by pumps  
3 located on the host (such as a floating platform), provide a  
4 net downward force on the assembly shown in Figure 33. There  
5 are several different modes of operation that amount to  
6 different preferred embodiments of the invention.

7  
8 In a first preferred embodiment, the Progressive Cavity  
9 Pump is turned on, valves 6980 and 7000 are closed, and valve  
10 7832 is open. Here, the volume pumped by the Progressive  
11 Cavity Pump is  $\Delta V_2$  is equal to  $\Delta V_3$ . Further, the volume  
12 pumped  $\Delta V_3$  is equal to the fluid displaced in the flowline  
13 during the downward travel of the apparatus shown in  
14 Figure 33. Therefore, if any portion of the flowline is open  
15 to a reservoirs, or other source of fluid, below the  
16 apparatus shown in Figure 33 (in region 6802), no fluid will  
17 be forced into those reservoirs, or other sources of fluid  
18 due to the downward motion of that apparatus. In another  
19 embodiment of the invention, the volume pumped by the  
20 Progressive Cavity Pump  $\Delta V_2$  is always equal to, or greater  
21 than  $\Delta V_3$ . In yet another embodiment of the invention, the  
22 volume pumped by the Progressive Cavity Pump is  $\Delta V_2$  is  
23 substantially equal to  $\Delta V_3$ . Many other variants of this  
24 preferred embodiment are possible. This particular method of  
25 conveyance of coiled tubings into cased wellbores was  
26 substantially described on page 67, lines 53-67, and on  
27 page 68, lines 1-4, of U.S. Patent No. 6,387,946 B1.

28  
29 In a second preferred embodiment, the Progressive Cavity  
30 Pump is turned off, valves 6980, 7000, and 7832 are open, and  
31 the pressure P forces Electric Flowline Immersion Heater  
32 Assembly ("EFIHA") 7723 down into flowline 6782.

33  
34  
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1           **Figure 34** shows yet another preferred embodiment of the  
2 invention that shows an Electric Flowline Immersion Heater  
3 Assembly ("EFIHA") 7727 generally disposed in a flowline  
4 6782. Element 6806 shows the annular portion of the wellbore  
5 below the EFIHA, element 6808 shows the annular region of the  
6 well above the Retrieval Sub 7180 and below the inflatable  
7 packer 7900, and the region of the well above the inflatable  
8 packer 7726 has been previously defined. The other numerals  
9 have already been defined in Figure 34. Functionally, this  
10 is very similar to the "second preferred embodiment"  
11 described in the previous paragraph. The Smart Shuttle in  
12 Figure 33 has been removed to make the apparatus in  
13 Figure 34. In this embodiment, valve 7832 is open, and the  
14 pressure P forces Electric Flowing Immersion Heater Assembly  
15 ("EFIHA") 7727 into the flowline. This installs the  
16 Electrically Heated Composite Umbilical ("EHCUC") 7725 within  
17 flowline 6782.

18  
19           **Figure 35** shows cased well 1060 penetrating the sea  
20 bottom 1064 at location 1068. Steel cased well 1060 is  
21 attached to XMas Tree 1072 having control means 1076. The  
22 XMas Tree 1072 is attached to steel flowline 1080 that lies  
23 on the sea bottom until location 1084. At location 1084 the  
24 flowline begins its ascent to the upper portion of the  
25 flowline 1088, also known as a riser, that is connected to  
26 floating platform 1092.

27  
28           For the purposes of this invention, the term "Xmas  
29 Tree", "subsea wellhead", and "wellhead" may be used  
30 interchangeably.

31  
32           **Figure 35** shows an Electrically Heated Composite  
33 Umbilical ("EHCUC") 1096 being installed within the flowline  
34 1080 by tractor means 1100 having retractable traction wheels

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1 1104 and 1108, tractor body 1112, tractor locking mechanisms  
2 1116 and 1120, cablehead 1124 obtaining electrical power and  
3 control signals from wireline 1128 (which may also be an  
4 umbilical). The cablehead provides electrical power and  
5 control signals to the tractor body through connector 1132  
6 which in turn provides electrical power and control signals  
7 to run the electrical motors that energize the traction  
8 wheels. The floating platform floats in ocean 1136 having  
9 ocean surface 1140.

10  
11 In Figure 35, the EHCU is locked to the tractor means by  
12 the tractor locking mechanisms. The traction wheels of the  
13 tractor means drags the EHCU into the flowline. After the  
14 EHCU reaches a particular distance Z35 away from the XMas  
15 Tree, then the traction wheels are turned off. The legend  
16 Z35 is defined in Figure 35. Thereafter, the tractor locking  
17 mechanisms are released, and the traction wheels of the  
18 tractor means are retracted into the body of the tractor.  
19 The tractor means is then pulled out of the well by pulling  
20 on the wireline 1128. The EHCU is left installed in place  
21 within the flowline. Not shown in Figure 35 are locking  
22 mechanisms 1122 and 1123 on the EHCU which will lock it in  
23 place within the flowline during production operations.  
24 In one preferred embodiment, produced oil and gas flows  
25 through the interior of the EHCU 1141 to the surface. In  
26 another preferred embodiment, produced oil and gas flows  
27 through the region between the inside diameter of the  
28 flowline and the outside diameter of the EHCU that is  
29 region 1142 in Figure 35. In yet another embodiment, the  
30 production can flow through both regions 1141 and 1142.

31  
32 In Figure 36, steel cased well 1144 is located within a  
33 geological formation 1148 that penetrates the sea bottom 1152  
34 at location 1156. Steel cased well terminates in XMas Tree

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1 1160 having control means 1164. Steel flowline 1168 is  
2 attached to the XMas Tree and rests on the bottom of the  
3 sea until location 1172 at which point it raises towards  
4 the upper end of the flowline, which is riser 1174, that  
5 is connected to Floating Production, Storage and Offloading  
6 (FPSO) ship 1176.

7  
8 The Pump-Down Conveyed Flowline Immersion Heater  
9 Assembly ("PDCFIHA") is generally shown as element 1180 in  
10 Figure 36. A portion of this apparatus includes an  
11 Electrically Heated Composite Umbilical ("EHCUC") 1184.  
12 Hydraulic pressure P in the annular space between the inside  
13 diameter of the flowline and the outside diameter of the  
14 EHCUC, which space is designated by numeral 1188 in Figure 36,  
15 applies a force F to the hydraulic seals 1192 attached to the  
16 PDCFIHA. Three seals are shown in Figure 36 which are  
17 collectively labeled as element 1192 in Figure 36. The  
18 hydraulic pressure P is used to carry the PDCFIHA into place  
19 a distance Z36 away from the XMas Tree. The legend Z36 is  
20 defined in Figure 36.

21  
22 If the control means 1164 has closed a valve connecting  
23 the flowline to the XMas Tree, then the displaced fluid from  
24 annular region 1196 must go somewhere. A downhole pump motor  
25 assembly is generally shown as element 1200 in Figure 36  
26 which is very similar to that shown in Figure 8 herein. So,  
27 the detailed elements of the downhole pump motor assembly  
28 will not be labeled in the interests of simplicity. However,  
29 this downhole pump motor assembly possesses hydraulic pump  
30 1204 that energized by electrical motors 1208 and 1212.  
31 Crude production flows into orifice 1214 of the hydraulic  
32 pump, and exits from the orifices collectively identified  
33 with numeral 1216 in Figure 36. This exiting fluid is  
34 trapped within pump shroud 1220 that is attached to the EHCUC

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1 at location 1224. Electrical power and control signals are  
2 provided by internal conductors and/or fiber optic cables  
3 within the walls of the EHCU, are broken out of the wall of  
4 the EHCU by apparatus 1228 that provides power and control  
5 signals to the downhole pump motor assembly by jumper 1232.  
6 The fluid then flows through the pump shroud and then through  
7 the EHCU towards the upper portion of the EHCU 1236 that is  
8 connected to the FPSO ship. If the volume produced by the  
9 hydraulic pump "V35P" exceeds the volume "V35D" displaced by  
10 the downward movement of the PDCFIHA, then the PDCFIHA can  
11 proceed into the well.  
12

13 Even if the control means 1164 allowed the valve from  
14 the flowline to the cased well to remain open (said valve is  
15 not shown in Figure 36 for simplicity), as long as V35P  
16 exceeds the volume V25D, then no fluid will flow back into  
17 the steel cased well. FPSO ship is located in ocean 1240  
18 having ocean surface 1244.  
19

20 **Figure 37** is very similar to Figure 36, except here  
21 the host is floating platform 1248. All the other numerals  
22 in Figure 37 have already been otherwise identified and  
23 described in Figure 36.  
24

25 In **Figure 37A**, all the numerals have been defined except  
26 those described in the following within this paragraph.  
27 Locks 1221 and 1222 serve to lock the "PDCFIHA" into place  
28 after it has been pumped down into the well. In one  
29 preferred embodiment, cross-over valve 1249 allows fluid  
30 flowing in region 1250 between the downhole pump motor  
31 assembly 1200 and the pump shroud 1220 to be directed into  
32 annular region 1188. Then production would flow through  
33 annular region 1188 to the surface. In yet another  
34 embodiment of the invention, the cross-over valve 1249 would

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1 allow fluid to not only flow through annular region 1128 to  
2 the surface but fluid would also be allowed to flow in the  
3 inside of the EHCU 1251 in that portion of the EHCU that is  
4 between the floating platform and cross-over valve 1249.  
5 In yet another embodiment, the cross-over valve 1249 may be  
6 chosen to direct production to region 1251 only; to region  
7 1184 only; and to regions 1251 and 1184 simultaneously.  
8 After the locks 1221 and 1222 are deployed, the hydraulic  
9 pump 1204 may be used to assist well production by providing  
10 artificial lift.  
11

12 In **Figure 38**, all the elements having numerals less than  
13 280 have been described in relation to Figure 9 herein.  
14 However, casing 274 in Figure 38 may also include other forms  
15 of tubulars, including tubing. Open hole completion 1252 in  
16 a reservoir with heavy oil 1256 causes heavy oil 1260 to flow  
17 through expanded screen 1262 into the open hole 1264. Heavy  
18 oil flows into the inflow assembly 1268, thorough intake  
19 orifice 1272, into hydraulic pump 1276, and out exhaust  
20 orifices that are collectively labeled with 1280 in  
21 Figure 38. Electric motors 1284 and 1288 provide the power  
22 to drive the hydraulic pump. After the heavy oil emerges  
23 from the exhaust orifices, it is trapped by shroud 1292 that  
24 is connected to Electrically Heated Composite Umbilical  
25 ("EHCU") 1296. The annular region inside the shroud open to  
26 fluid flow is defined by numeral 1294. The heated production  
27 proceeds through the inside of EHCU 1298 towards the top of  
28 the EHCU 1300 attached to platform 258. Electrical power and  
29 control signals are provided to the electric motors by  
30 electrical conductors and by fiber optic fibers within the  
31 wall thickness of the EHCU. The hydraulic pump provides  
32 artificial lift to the heavy oil produced.  
33  
34

1           The Electric Flowline Immersion Heater Assembly  
2   ("EFIHA") is generally designated with element 1304 in  
3   Figure 38 which includes the Electrical Heated Composite  
4   Umbilical 1296. In this case, hydraulic pressure P applied  
5   at the platform in the annular region between the outside  
6   diameter of the EHCU and the inside diameter of the casing  
7   274, which is region 1308, provides a force on seals 1312  
8   that forces the EFIHA down into the well. Guides 1316 help  
9   centralize the EFIHA. As the EFIHA is forced downhole, a  
10   certain displaced fluid volume V38D could be forced back into  
11   formation which could damage the formation. However, if the  
12   hydraulic pump forces a volume V38P into the EHCU, then  
13   provided that V38P is greater than V38D at all times, then no  
14   fluid is forced back into the open hole. This is important  
15   to prevent formation damage from "back flow".  
16

17           In one of the preferred embodiments above, fluid flow  
18   from the open hole 1264 is caused to flow through region 1294  
19   and then through the interior of the EHCU 1290 to the  
20   surface. As described above, a cross-over valve can be  
21   installed that will allow production to flow instead through  
22   region 1308 to the surface. And yet another embodiment would  
23   allow production to flow through both regions 1298 and 1308  
24   to the surface.  
25

26           The EHCU provides heat to reduce the viscosity of the  
27   heavy oil produced from the open hole. Therefore, the  
28   artificial lift provided by the hydraulic pump is used  
29   efficiently to produce heavy oil.  
30

31           Figure 39 shows an exploratory well with large volume  
32   fluid sampling capability. Figure 39 shows a floating  
33   platform 1320 with a small separator with fluid storage 1324  
34   in ocean 1328 having ocean surface 1330. Marine blowout

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1     preventer ("BOP") 1332 is shown on ocean bottom 1336 at  
2     location 1340. Borehole 1344 penetrates a first geological  
3     formation 1348, a second geological formation 1352, and a  
4     third geological formation 1356 in earth 1360. Casing 1364  
5     penetrates the BOP and lines the borehole down to location  
6     1368. Perforations 1370 were made into producing intervals  
7     in the first geological formation 1348. Downhole sampling  
8     unit shown as element 1372 in Figure 39 possesses an open  
9     hole packer, with a sand screen filter, and a pump. The pump  
10    is used to pump samples up insulated and heated coiled tubing  
11    1376 through the casing to the small separator with fluid  
12    storage 1324 on the floating platform. Perforations 1380  
13    were made into intervals to be tested in second geological  
14    formation 1352. In a preferred embodiment, electrical power  
15    to operate the pump is obtained from electrical wires that  
16    are in the wall thickness of an umbilical as described  
17    earlier. On another preferred embodiment the heated tubing  
18    is comprised of an Electrical Heated Composite Umbilical  
19    (EHCU) as previously described above.

20  
21         In relation to Figure 39, heated coiled tubing that is  
22    pumped will allow large reservoir fluid samples to be  
23    collected without the expense of a downhole completion. In  
24    an emergency, the coiled tubing is cut at the marine BOP and  
25    the downhole pump shuts in the coiled tube to prevent a  
26    blowout path. Applications include areas with soft sandstone  
27    and areas where larger fluid volumes are required to  
28    determine the reservoir production fluid properties.

29  
30         Figure 40 shows an apparatus that provides power to  
31    upstream functions. In preferred embodiments, this would  
32    apply to subsea systems that are external to a flowline.  
33    In Figure 40, flowline 1384 is in the vicinity of a subsea  
34    installation 1388 that requires electrical power. Composite

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1 umbilical 1392 is attached to first assembly 1396. Composite  
2 umbilical 1392 possesses electrical wires within its wall  
3 thickness that are broken out by assembly 1400 that is  
4 connected to jumper 1404. The electrical power is used to  
5 energize electric motor 1408 that is used to energize  
6 Progressing Cavity Pump 1412. As has been described in  
7 relation to other embodiments above, pressure provided by an  
8 external source in the annular region between the outside  
9 diameter of the composite umbilical and the inside diameter  
10 of the flowline acting on hydraulic seal 1416 forces the  
11 entire apparatus collectively called the "Connector  
12 Apparatus" 1420 into the flowline. The annular region  
13 between the outside diameter of the composite umbilical and  
14 the inside diameter of the flowline is defined as element  
15 1386 in Figure 40. As previously described, the Progressing  
16 Cavity Pump, in conjunction with seals 1424, is used to pump  
17 displaced fluid through channel 1428 into the interior of the  
18 composite umbilical 1432 for return to the surface. Landing  
19 and locating shoulder 1436 is used to provide electrical  
20 power to the flowline penetrating connector 1440. Subsea  
21 power cable 1444 is attached to the flowline penetrating  
22 connector 1440. The flowline penetrating connector 1440 is  
23 placed into its proper position 1448 by an ROV. In various  
24 different embodiments, the flowline is penetrated for  
25 electrical, chemical and hydraulic power. This approach  
26 minimizes umbilical costs to small installations.

27  
28 Figure 41, all the elements through element 506 have  
29 been defined previously. In addition, two of the  
30 electrically insulated wires 1452 and 1456 are used to  
31 uniformly electrically heat composite umbilical 1460 in  
32 Figure 41.

33  
34  
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1           **Figure 42** shows one embodiment of a first resistor  
2 network used to electrically heat composite umbilicals.  
3 Here, wires 1452 and 1456 have uniform resistance per unit  
4 length. The total resistance of each one of these  
5 electrically insulated wires is  $R(42)$  in ohms. These wires  
6 are connected together at the lower end of the composite  
7 umbilical shown by electrical jumper 1464. The total length  
8 of each wire in the composite umbilical is  $L(42)$ , a legend  
9 that is defined on Figure 42. The legend  $V(42)$  in Figure 42  
10 shows the voltage  $V(42)$  applied uphole to the resistive  
11 network. This first resistive network will result in uniform  
12 heating of the electrically heated composite umbilical.  
13

14           In **Figure 43**, all the elements through elements 506 have  
15 been define previously. In addition, two of the electrically  
16 insulated wires 1468 and 1472 are used to nonuniformly heat  
17 composite umbilical 1476.  
18

19           **Figure 44** shows an embodiment of a second resistor  
20 network used to nonuniformly electrically heat composite  
21 umbilicals. Here, wire 1468 does not have a uniform  
22 resistance per unit length. In Figure 44, wire 1472 has  
23 uniform resistance per unit length (but in other embodiments,  
24 this need not be the case). Wires 1468 and 1472 are  
25 connected together at the lower end of the composite  
26 umbilical by a short electrical jumper 1480 having negligible  
27 electrical resistance. The length of the electrically heated  
28 composite umbilical is  $L(44)$  and that legend is defined in  
29 Figure 44. Wire 1472 has a uniform resistance per unit  
30 length, and has a total resistance in ohms of  $R(44D)$ , a  
31 legend that is defined in Figure 44. Wire 1468 has a  
32 resistance in ohms of  $R(44A)$  during a first length  $L(44)/3$ ;  
33 has a resistance in ohms of  $R(44B)$  during a second length  
34  $L(44)/3$ ; and has a resistance in ohms of  $R(44C)$  during a

1 third length of  $L(44)/3$ . The legends  $R(44A)$ ,  $R(44B)$ , and  
2  $R(44C)$  are defined in Figure 44. Many ways may be used to  
3 fabricate wire 1468, including suitably joining together  
4 different sections of different wires having different  
5 resistances per unit length, but otherwise having the same  
6 outside diameters of insulation. The legend  $V(44)$  in  
7 Figure 44 shows the voltage  $V(44)$  applied uphole to the  
8 resistor network. The total resistive load is the sum of  
9  $R(44A)$ ,  $R(44B)$ ,  $R(44C)$ , and  $R(44D)$ . If  $R(44C)$  is greater  
10 than  $R(44B)$ ; and if  $R(44B)$  is greater than  $R(44A)$ ; and if  
11  $R(44A)$  is greater than  $R(44D)$ ; then the electrically heated  
12 composite umbilical will preferentially apply more electrical  
13 heat to the lower (right-hand side) of the umbilical in  
14 Figure 44. This nonuniform electrical heating has many  
15 advantages including the application of heat in poorly  
16 insulated areas of an umbilical or coiled tubing; the  
17 matching of required heat to the transportation process of  
18 hydrocarbons within the umbilical or coiled tubing to  
19 avoid the build up of waxes and hydrates such as the  
20 preferential heating of areas where high J-T cooling may  
21 exist; etc.

22  
23 **Figure 45** shows another preferred embodiment of the  
24 electrically heated umbilical that is labeled with numeral  
25 1484 that is an armored electric cable umbilical. Steel or  
26 synthetic armor 1488 surrounds filler 1492 that encapsulates  
27 electrical wires 1496 surrounded by electrical insulation  
28 1500. This preferred embodiment can include certain types of  
29 logging cables. The wires may be individual wires, pairs,  
30 bundles, etc. The cable may have some wires dedicated to  
31 communication, some for power and fiber optic fibers (not  
32 shown in Figure 45) for communication and sensor service.  
33 For heating the production (besides losses due to routine  
34 power transmission losses) circuits may be dedicated to

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1 heating applications as described earlier. Sections of the  
2 circuits may be designed for heating, thus the heat can be  
3 directed to specific locations along the umbilical length as  
4 described in other embodiments above.

5  
6 **Figure 46** shows another preferred embodiment of the  
7 electrically heated umbilical generally designated as element  
8 1504. The umbilical is surrounded by steel coiled tubing  
9 1508 having any desirable outside diameter and having any  
10 desirable wall thickness. Electric cable 1512 provides  
11 electrical power for devices, provides communication service,  
12 and provides electrical power for electrical heating of  
13 fluids within region 1516 of the coiled tubing which may be  
14 retrofitted into the steel coiled tubing to be replaced or  
15 repaired. To replace cable 1512 after the steel tubing was  
16 installed into a flowline, it may be pulled out of the steel  
17 tubing leaving the steel tubing within the flowline. Then a  
18 hydraulic seal between the outside diameter of the cable and  
19 the inside diameter of the steel coiled tubing allows  
20 hydraulic pressure introduced into that annular area to be  
21 used to force down the cable into the steel coiled tubing.  
22 The outside diameter of electric cable is dependent upon the  
23 application for which it is chosen. In one preferred  
24 embodiment, hot fluid is circulated down region 1516 and the  
25 umbilical is used as an immersion heater. In another  
26 preferred embodiment, electric current goes down the electric  
27 cable and is conducted back up the coiled tubing that  
28 provides immersion heating. In yet another embodiment, all  
29 the heating comes from the power dissipated within electrical  
30 circuits within the electric cable. In yet other preferred  
31 embodiments, cable 1512 may also contain fiber optic cables,  
32 hydraulic tubes, etc. for other applications.

33  
34  
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1           **Figure 47** shows yet another embodiment of the  
2 electrically heated umbilical 1520 that is similar to that  
3 shown in Figure 46, except here an extra thermal insulation  
4 layer 1524 is bonded to the outside of the steel coiled  
5 tubing. Umbilical 1520 is a thermally insulated umbilical  
6 with an electric cable. Here, the electric cable includes  
7 wires for heating the pipe, wires for control and power of a  
8 downhole electric pump, and fiber optic cables for measuring  
9 distributed temperature.

10  
11           **Figure 48** shows yet another embodiment of the  
12 electrically heated umbilical 1528 that is called a bundled  
13 umbilical. Outer wear sheath 1532 surrounds filler or  
14 potting material 1536 which surrounds one or more electric  
15 cables 1540. Each such electric cable provides functions  
16 described in the previous paragraph. In addition, the  
17 potting material surrounds one or more tubes 1544 having  
18 channels 1548. The tubes may carry any fluid or chemical to  
19 the end of the umbilicals. For example, these fluids may  
20 include an emulsion breaker that is injected just upstream of  
21 a pump. The electric cables provide power and communication,  
22 and may provide distributed electrical heating. The filler  
23 binds the umbilical together and provides for control of the  
24 buoyancy of the umbilical.

25  
26           Figures 28 and 29 show existing flowlines installed in a  
27 producing oil field. Any of the Electric Flowline Immersion  
28 Heater Assemblies shown in Figures 30, 31, 32, 33, 34, 35, 36,  
29 37, and 37A may be retrofitted into existing flowlines. The  
30 Electric Flowline Immersion Assemblies shown in these figures  
31 are different embodiments of "electric flowline immersion  
32 assembly means". Therefore, the "Electric Flowline Immersion  
33 Heater Assembly" ("EFIHA"), the "Electric Flowline Immersion  
34 Heater Assembly with Wireline Smart Shuttle" ("EFIHAWSS"),

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1 the "Smart Shuttle Conveyed Electric Flowline Immersion  
2 Heater Assembly ("SSCEFIHA"), and the "Pump-Down Conveyed  
3 Flowline Immersion Heater Assembly" ("PDCFIHA"), are all  
4 different embodiments of "electric flowline immersion  
5 assembly means".  
6

7 In accordance with the preferred embodiments herein, any  
8 of the Electrically Heated Composite Umbilicals shown in  
9 Figures 30, 31, 32, 33, 34, 35, 36, 37, and 37A may be  
10 retrofitted into existing flowlines which are different  
11 embodiments of "electrically heated composite umbilical  
12 means" which are used to make "immersion heater means".  
13 In accordance with the preferred embodiments herein, the  
14 additional types of electrically heated umbilical immersion  
15 heaters shown in Figures 41, 43, 45, 46, 47, and 48 may be  
16 suitable retrofitted into existing flowlines and they are  
17 different preferred embodiments of "electrically heated  
18 umbilical means" that are used to make "immersion heater  
19 means".  
20

21 Any of the umbilical conveyance means shown in  
22 Figures 30, 31, 32, 33, 34, 35, 36, 37, and 37A may be used  
23 to install any of the "electrically heated umbilical means"  
24 or the "electrically heated composite umbilical means" into a  
25 flowline to make "immersion heater means". As described in  
26 the preferred embodiments, these are installed with different  
27 embodiments of "electric flowline immersion assembly means"  
28 which provide different means to install, or remove, the  
29 electric flowline immersion assembly means from the well.  
30 Any means that is used to convey into a flowline, or remove  
31 from a flowline, any "electrically heated umbilical means"  
32 shall be defined herein as a "conveyance means to install an  
33 electrically heated umbilical means in a flowline". Any  
34 means that is used to convey into a flowline, or remove from

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1 a flowline, any "electrically heated composite umbilical  
2 means" shall be defined for the purposes herein as a  
3 "conveyance means to install an electrically heated composite  
4 umbilical means".  
5

6 It is important to be able to retrofit such electrically  
7 heated immersion heater systems into existing flowlines for  
8 many reasons that includes the following:

9 (a) to introduce an immersion heater system into an  
10 existing flowline that was not expected to have wax or  
11 hydrate build-up problems;

12 (b) to have repair alternatives for previously  
13 installed, but failed, permanent heating systems; and

14 (c) to have operating flexibility to adapt the  
15 production system to different production characteristics  
16 from original expectations.  
17

18 Electrically heated immersion heater systems can be  
19 installed to prevent waxes and hydrates from forming.  
20 Hydrates are a solid ice-like materials typically composed of  
21 water and low molecular weight gases such as methane.  
22 Hydrates form in high-pressure, low temperature, environments  
23 such as those found in subsea production systems. Hydrates  
24 may easily plug production systems, especially during  
25 transient operating conditions if not properly managed.  
26

27 In many of the preferred embodiments, a pump is  
28 installed in the flowline and may be used in combination with  
29 the electrically heated immersion heater system, which has  
30 many advantages, including the following:

31 (a) such methods and apparatus increases the production  
32 recovery rate helping the field's net present value ("NPV");  
33 and  
34

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1           (b) such methods and apparatus increases the total  
2 recoverable reserves from the reservoir by reducing the  
3 backpressure on the reservoir.  
4

5           The installation of an electrically heated immersion  
6 heater system in a flowline heats up any produced heavy oils  
7 which reduces the viscosity of the produced heavy oils, which  
8 has many advantages, including the following:

9           (a) such methods and apparatus reduces the pumping  
10 energy required to transport produced hydrocarbons through  
11 the flowline which therefore reduces the costs of producing  
12 the hydrocarbons;

13           (b) such methods and apparatus makes some presently  
14 non-commercial fields economic to develop; and

15           (c) such methods and apparatus allows for the efficient  
16 subsea transportation of typical gelling crude oils.  
17

18           In many of the preferred embodiments described,  
19 nonuniform heating may be applied to the flowline(s) by the  
20 electrically heated immersion heater system which provides  
21 many advantages, including being able to configure the  
22 production facility to better match and manage the thermal  
23 requirements for heating of the flowline(s) to avoid build up  
24 of waxes and hydrates, and to reduce the cost of producing  
25 hydrocarbons from the reservoir.  
26

27           Other preferred embodiments provide for the dynamic  
28 reconfiguring of the heat supplied by an electrically heated  
29 umbilical after the umbilical is installed into a flowline.  
30 As an example of such a preferred embodiment, the value of  
31 R(44C) in Figure 44 can be selectable, and controlled from a  
32 surface computer. There are a variety of means for doing so,  
33 including computer controlled switches in the wall of an  
34

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1 Electrically Heated Composite Umbilical that can be used to  
2 switch in, or out, certain resistor circuits.

3  
4 Yet other preferred embodiments provide for the dynamic  
5 reconfiguring the buoyancy of an electrical heated umbilical.  
6 For example, computer controlled valves may distribute  
7 different densities of fluids within one or more fluid  
8 channels located within the wall of an Electrically Heated  
9 Composite Umbilical. Such systems are described in detail in  
10 Provisional Patent Application Number 60/432,045, filed on  
11 December 8, 2002, and in U.S. Disclosure Document  
12 No. 531,687 filed May 18, 2003, entire copies of which are  
13 incorporated herein by reference.

14  
15 In many of the preferred embodiments described, the  
16 electrically heated immersion heater system may be removed  
17 from the well, repaired, and retrofitted in the flowline  
18 without removing the flowline which provides many advantages,  
19 including the following:

20 (a) such methods and apparatus saves significant  
21 operating costs by performing both the heater and artificial  
22 lift pump service from the host facility without having to  
23 mobilize a subsea intervention vessel; and

24 (b) such methods and apparatus allows for the use of  
25 conventional electric submersible pumps for critical subsea  
26 "tie-back services" to the host.

27  
28 The term "tie-back service" has been used above.  
29 Satellite production wells are frequently used to develop  
30 small fields surrounding an existing facility to which they  
31 are connected, and from which they are controlled. These  
32 satellite wells provide tie-back service to the host  
33 production facility.

34  
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1           In view of the above disclosure, a preferred embodiment  
2 of the invention is an apparatus comprising an electrically  
3 heated composite umbilical means installed within a subsea  
4 flowline containing produced hydrocarbons as an immersion  
5 heater means to prevent waxes and hydrates from forming  
6 within the flowline and blocking the flowline, whereby the  
7 electrically heated composite umbilical means possesses at  
8 least one electrical conductor disposed within the composite  
9 umbilical means that conducts electrical current that is used  
10 to heat the electrically heated composite umbilical means  
11 within the subsea flowline.  
12

13           In view of the above disclosure, a preferred embodiment  
14 of the invention is a method of installing an electrically  
15 heated composite umbilical means within a previously existing  
16 subsea flowline containing produced hydrocarbons to make an  
17 immersion heater means to prevent waxes and hydrates from  
18 forming within the flowline and blocking the flowline.  
19

20           In view of the above disclosure, a preferred embodiment  
21 of the invention is a method of using an umbilical conveyance  
22 means to convey into an existing subsea flowline possessing  
23 produced hydrocarbons an electrically heated composite  
24 umbilical means used as an immersion heating means to prevent  
25 waxes and hydrates from forming within the flowline and  
26 blocking the flowline.  
27

28           In view of the disclosure above, a preferred embodiment  
29 of the invention is a method of using an umbilical conveyance  
30 means to convey into an existing subsea flowline containing  
31 produced hydrocarbons an electrically heated umbilical means  
32 used as an immersion heating means to prevent waxes and  
33 hydrates from forming within the flowline and blocking  
34 the flowline.

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1           In view of the above, a preferred embodiment of the  
2 invention is a method of providing artificial lift to  
3 produced hydrocarbons within a subsea flowline comprising at  
4 least the steps of:

5           (a) attaching a progressing cavity pump to an electric  
6 motor to make an electrically energized pump;

7           (b) attaching the electrically energized pump to  
8 to a first end of a tubular composite umbilical possessing a  
9 multiplicity of electrical conductors within the wall of the  
10 tubular composite umbilical;

11           (c) conveying into the flowline the electrically  
12 energized pump attached to the first end of the composite  
13 tubular umbilical;

14           (d) using first and second of a multiplicity of  
15 electrical conductors to electrically heat the composite  
16 umbilical to prevent waxes and hydrates from blocking the  
17 flow of the produced hydrocarbons within the flowline; and

18           (e) using at least third and fourth electrical  
19 conductors of the multiplicity of electrical conductors to  
20 provide electrical energy to the electrically energized pump,  
21 whereby the progressing cavity pump provides artificial lift  
22 to the produced hydrocarbons within the subsea flowline.  
23

24           In view of the above, a preferred embodiment of the  
25 invention is a method of providing artificial lift to  
26 produced hydrocarbons within a subsea flowline comprising at  
27 least the steps of:

28           (a) attaching a hydraulic pump to an electric motor to  
29 make an electrically energized pump;

30           (b) attaching the electrically energized pump to  
31 to a first end of a tubular composite umbilical possessing a  
32 multiplicity of electrical conductors within the wall of the  
33 tubular composite umbilical;  
34

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1           (c) conveying into the flowline the electrically  
2 energized pump attached to the first end of the composite  
3 tubular umbilical;

4           (d) using first and second of the multiplicity of  
5 electrical conductors to electrically heat the composite  
6 umbilical to prevent waxes and hydrates from blocking the  
7 flow of the produced hydrocarbons within the flowline; and

8           (e) using at least third and fourth electrical  
9 conductors of the multiplicity of electrical conductors to  
10 provide electrical energy to the electrically energized pump,  
11 whereby the electrically energized pump provides artificial  
12 lift to the produced hydrocarbons within the subsea flowline.

13  
14           In yet another preferred embodiment of the invention, an  
15 electrical heated composite umbilical means dissipating in  
16 excess of 60 kilowatts of electrical energy to heat produced  
17 hydrocarbons is installed within a flowline to prevent the  
18 formation of waxes and hydrates and blockage of the flowline.

19  
20           In another preferred embodiment of the invention, an  
21 electrical heated umbilical means dissipating in excess of 60  
22 kilowatts of electrical energy to heat produced hydrocarbons  
23 is installed within a flowline to prevent the formation of  
24 waxes and hydrates and blockage of the flowline.

25  
26           In yet another preferred embodiment of the invention,  
27 electrically heated composite umbilicals are approximately  
28 neutrally buoyant within the fluids present within the  
29 flowlines to reduce the frictional drag on the neutrally  
30 buoyant umbilicals when they are installed into the  
31 flowlines.

32  
33           Still further, in yet another preferred embodiment of  
34 the invention, electrically heated umbilicals are

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1 approximately neutrally buoyant within the fluids present  
2 within the flowlines to reduce the frictional drag on the  
3 neutrally buoyant umbilicals when they are installed into  
4 the flowlines.

5  
6 In another preferred embodiment of the invention, fluid  
7 filled electrically heated composite umbilicals are  
8 approximately neutrally buoyant within the fluids present  
9 within the flowlines to reduce the frictional drag on the  
10 neutrally buoyant umbilicals when they are installed into  
11 the flowlines.

12  
13 In yet another preferred embodiment of the invention,  
14 fluid filled electrically heated umbilicals are approximately  
15 neutrally buoyant within the fluids present within the  
16 flowlines to reduce the frictional drag on the neutrally  
17 buoyant umbilicals when they are installed into the  
18 flowlines.

19  
20 And finally, another preferred embodiment of the  
21 invention is using the methods and apparatus to drill and  
22 complete boreholes for infrastructure purposes such as for  
23 water, sewer, electric power, and communications facilities  
24 in metropolitan areas, and for subterranean pipelines in  
25 other suitable locations.

26  
27 While the above description contains many specificities,  
28 these should not be construed as limitations on the scope of  
29 the invention, but rather as exemplification of preferred  
30 embodiments thereto. As have been briefly described, there  
31 are many possible variations. Accordingly, the scope of the  
32 invention should be determined not only by the embodiments  
33 illustrated, but by the appended claims and their legal  
34 equivalents.

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